Forest Ecological Studies of the Montane Forest of Mt.Pangrango, West Java : III. Litter Fall of the Tropical Montane Forest near Cibodas

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III. Litter Fall of the Tropical Montane Forest near Cibodas

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Introduction

The present article deals with the litter production of a 1ha-plot, whose floristic composition was reported in the first paper of this series (Yamada 1975). After the summary of world litter production by Bray and Gorham (1964), studies concerned with litter have been reported from various parts of the world. Litter fall investigation in the tropics, however, has still covered only a restricted area and the measurement is not so accurate yet. The present investigation focusses on the litter production of species-units in the area studied.

Brief note on study area

The floristic compostion of the study area is typical montane rain forest in Southeast Asia and dominated by *Fagaceae, Lauraceae, Theaceae* in the higher strata, the lower strata being covered by *Escalloniaceae,* and *Saurauiaceae.* The altitude was estimated to be about 1550 m above sea level. The average annual rainfall was 3380 mm and the average annual temperature 17.9°C. As the rainfall data was not available for 1969 and 1970, data from Pacet Field Station, situated 6 km eastward of the study area was substituted as shown in Fig. 1. Although these data may not be representative of the study area, they must be similar. This figure shows a clear shortage of precipitation in June, July and August of 1969.

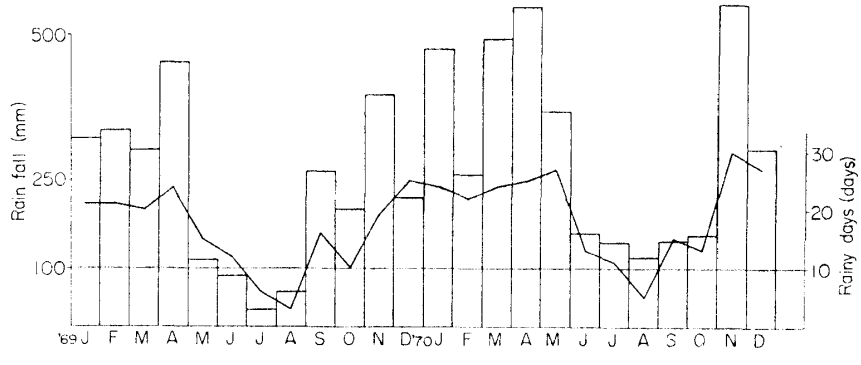

Fig. 1 Monthly rainfall and rainy days variation from January 1969 to December 1970 at Pacet, about 6 km east of Cibodas

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This trend cannot be so clearly distinguished in 1970. The dry season, a term which will be used in the following chapters refers mainly to these months of low rainfall.

Methods of study

Thirty-seven litter traps to catch the litter fall from the canopy were placed on the forest floor of 1ha-plot. Each trap was 1 m × 1 m in size and 20 cm in depth. The sides of the trap were made with boards and the bottom surface was covered by wire netting.

Every wednesday, the litter fall in one week was gathered for the first year and in the succeeding half year gathering was done at monthly intervals. Materials were air dried at the Cibodas Botanical Garden and divided into species-units of leaves, flowers, fruits and other components. After 48 hours oven-drying at 80°C, the weighing procedure was carried out in Japan using an electric microbalance whose minimum division was 0.01 gr.

Acknowledgements

The author wishes to express his thanks to Bapak Nurta, Sdr. Uden and Sdr. Idjung for their help in gathering, dividing and keeping the materials even after the author's departure from Indonesia, Dr. S. Yosida kindly checked the litter traps and materials in 1970, and Dr. K. Ogino brought back the material on his trip to Bali. LBN (National Biological Institute), Herbarium Bogeriense, under the helpful guidance of LIPI, generously rendered their good offices by sending the materials to Japan. Miss. Y. Imai and Mrs. K. Tanaka kindly helped the author during the process of writing this paper. Climatological data is owed to Mr. Rusdy E. Nasution of Kebun Raya Bogor. Prof. K. Iwatsuki kindly checked the species names of the ferns.

Results and Discussion

1. Basic statistics

The amount of total litter of each component is presented in Table 1. Total litter which includes all kinds of leaves, branches, fruits, flowers, insect bodies, feces, etc. is calculated to be 5.96 ton/ha·yr. This figure is not so large as in the tropics but is more or less simlar to those of the evergreen broadleaved forest in the temperate zone. For example, Tadaki and Kagawa (1968) reported 5.5–6.7 ton/ha. of litter of young *Castanopsis cuspidata* stands of southern Japan, and Kirita and Saito (1969) investigated a laurel forest of southern Japan where they found 4.8–8.1 ton/ha. of litter and Omura and Ando (1970) reported 6.26 ton/ha. in the same area of southern Japan. Kubiček (1970) reported 5.2 ton/ha. in Oak-hornbeam mixed forest, Sykes and Bunce (1970) also found 5.0–5.3 ton/ha. in a mixed deciduous forest of oak and ash. Judging from its floristic composition, this similarity seems quite normal.

Percentages of total leaves (75.6%) are also very similar, as in Omura's (74.1%) report. Branches (15.8%) are a rather high percentage, probably caused by the heavy rain in this

Table 1 Basic statistics of litter fall

Classification of litter	ton/ha.yr.	%
Leaves of trees and herbs	4.394	73.75
Leaves of ferns and fern allies	0.066	1.10
Leaves of orchids	0.029	0.49
Leaves of pandnus	0.001	0.02
Leaves of palms	0.014	0.24
Branchs	0.942	15.80
Barks	0.030	0.50
Usnea	0.002	0.04
Lichens	0.028	0.46
Mosses	0.016	0.26
Flowers	0.189	3.18
Fruits and seeds	0.201	3.38
Feces	0.011	0.19
Insect bodies	0.001	0.02
Others	0.034	0.56
	5.958	100.00

area. Flowers and Fruits account for 6.56% in total, usually more fruits are produced than flower in other sites of the world, but in this plot fruits were only slightly in excess of flowers.

2. Annual fluctuation of the total amounts of each component

Sixteen components of litter fall show the following seasonal pattern:

(1) Total litter (Fig. 2-1): The maximum point appears on the 24th December 1969, but this is only one exceptional peak. The first mode appears on the 20th August to 24th September 1969, which coincides with a rather dry period of the year, and other higher peaks appear on the 4th February, 18th March and the 29th April, which is supposedly caused by the heavy rain at this time of the year.

(2) Leaf litter (Fig. 2-2): The annual fluctuation of leaf litter shows a more distinctive pattern than the total litter, that is, the largest amount appears from the 20th August through to the 24th November, which is the latter part of the dry season.

(3) Branch litter (Fig. 2-3): This pattern is quite different from that of leaves. No fall occurs during the dry spell, but we find most of the fall occurs in the rainy season. Though the leaf litter has a definite physiological connection with the dry-wet climatological condition, branch litter seems to be affected by the physical force of pouring rain.

(4) Fern litter (Fig. 2-4): No distinct tendency appeared through the year, but the amount of litter was small during the dry period. Ferns are mostly epiphytes as mentioned in the succeding chapter.

(5) Tree ferns litter (Fig. 2-5): Not distinct, but a more or less larger amount could be seen

after the dry spell from the 1st October through to 26th November. The largest amount occured on the 19th November.

(6) Orchid litter (Fig. 2-6): Most of the species in this category are epiphytes. Three peaks appear in the figure, viz, the first is on the 9th July, the second is on the 10th September and the third is on the 4th February. The fomer two peaks coincide with the beginning and end of the dry season. The last peak is in the middle of the rainy season. The largest overall litter occurs in the latter part of the dry season.

(7) Usnea fall (Fig. 2-7): Usnea accounts for a small proportion of the total litter and the two peaks appear on the 11th February and the 18th March. It tends to fall throughout the rainy season. This may be caused by the heavy pouring rain.

(8) Lichen-fall (Fig. 2-8): Most of Lichen is epiphytic on the trees and no tendency could be recognized. They seemed to fall rather at random from the branches or trunks. From the 23rd July through to the 13th August, that is in the dry period, smaller amounts fall. The highest peak is on the 24th September and the next is on the 24th December. Between the two peaks, falling occurs constantly.

(9) Moss-fall (Fig. 2-9): This is very similar to Lichen, which shows random fluctuations throughout the year and has a minimum in the dry spell from the 16th July through to the 3rd September. The highest peak appears on the 7th January 1970. In general, fall occurs constantly throughout the rainy season.

(10) Pandnus-fall (Fig. 2-10): Pandnus species were distributed sparsely in the sample plot itself and litter fall occured only twice in the rainy season. Generally, pandnus grow more densely at lower altitudes on this mountain.

(11) Palm-fall (Fig. 2-11): Two distinct peaks appear here, one is on the 9th July and the other is on the 4th March, but the greater amount falls during the latter half of the rainy season. As the palm grows sporadically and its height is rather low, the frequency with which the leaf-fall is caught is controlled by the position of the litter traps.

(12) Flower litter (Fig. 2-12): A typical bimodal pattern is shown in this figure. One peak appears on the 9th July, that is at the beginning of the dry season and the other peak occurs on the 24th December, which corresponds with the middle of the rainy period of the year. We could recognize a small amount of flower litter even at two dropping points, which means the forest here always has flowering trees irrespective of the season, although two rather distinctive seasons exist.

(13) Furit-litter (Fig. 2-13): In relation to flower litter, fruit falls twice a year remarkably soon after the flower season. The highest peak appears on the 10th September. Fruit-fall is much greater in the dry period than in the rainy season. As stated under "Flower-litter", this forest always produces fruits, though the fruit product accounts for only a small proportion of the total litter quantity.

(14) Insect feces litter (Fig. 2-14): From the 28th January through to the 15th April, the figure shows a smaller amount than in other periods. And a more or less larger amount of

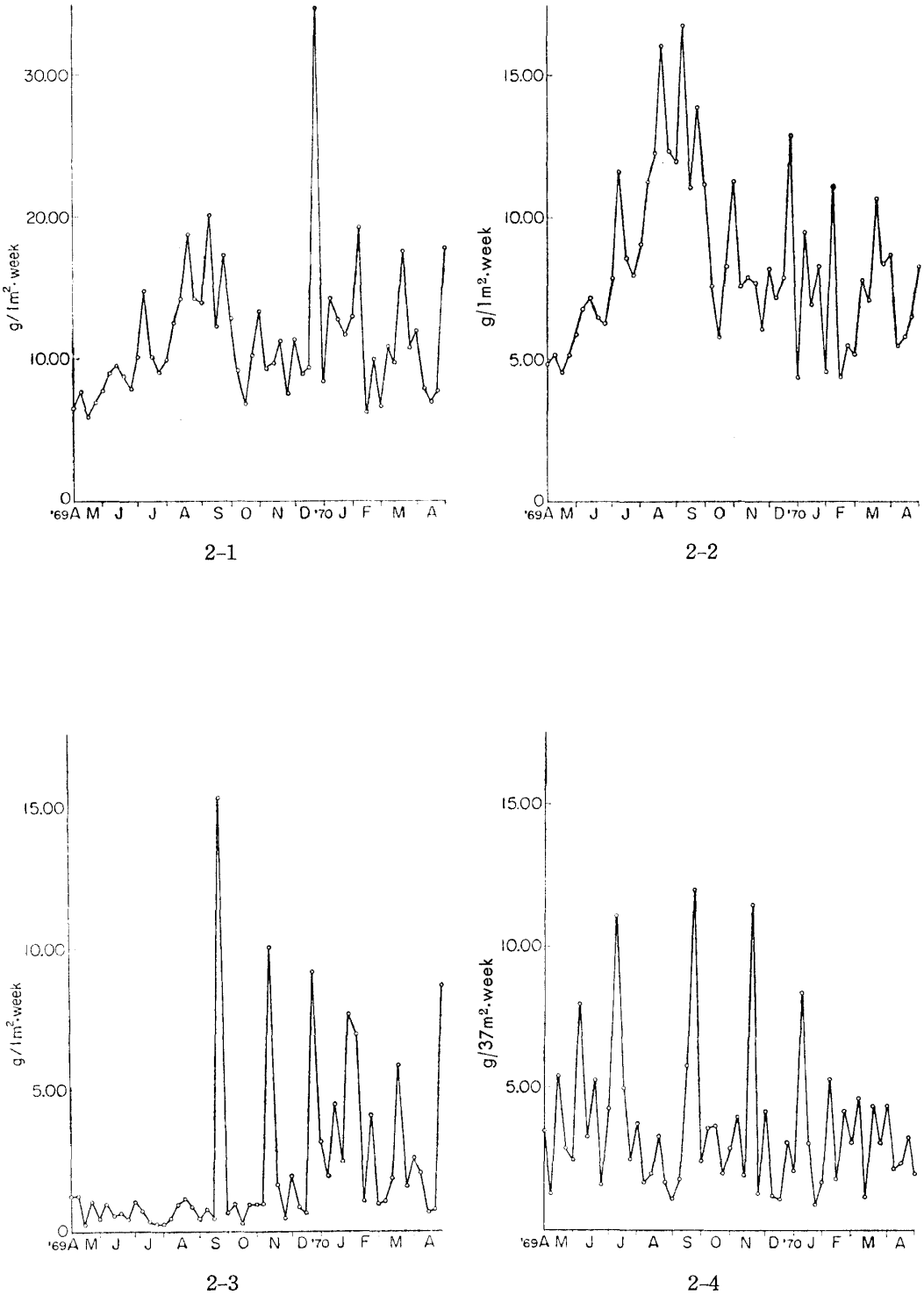


Fig. 2-1～4 Weekly amount of various kind of litter fall for one year at 1 ha-plot. Further notice, see text.

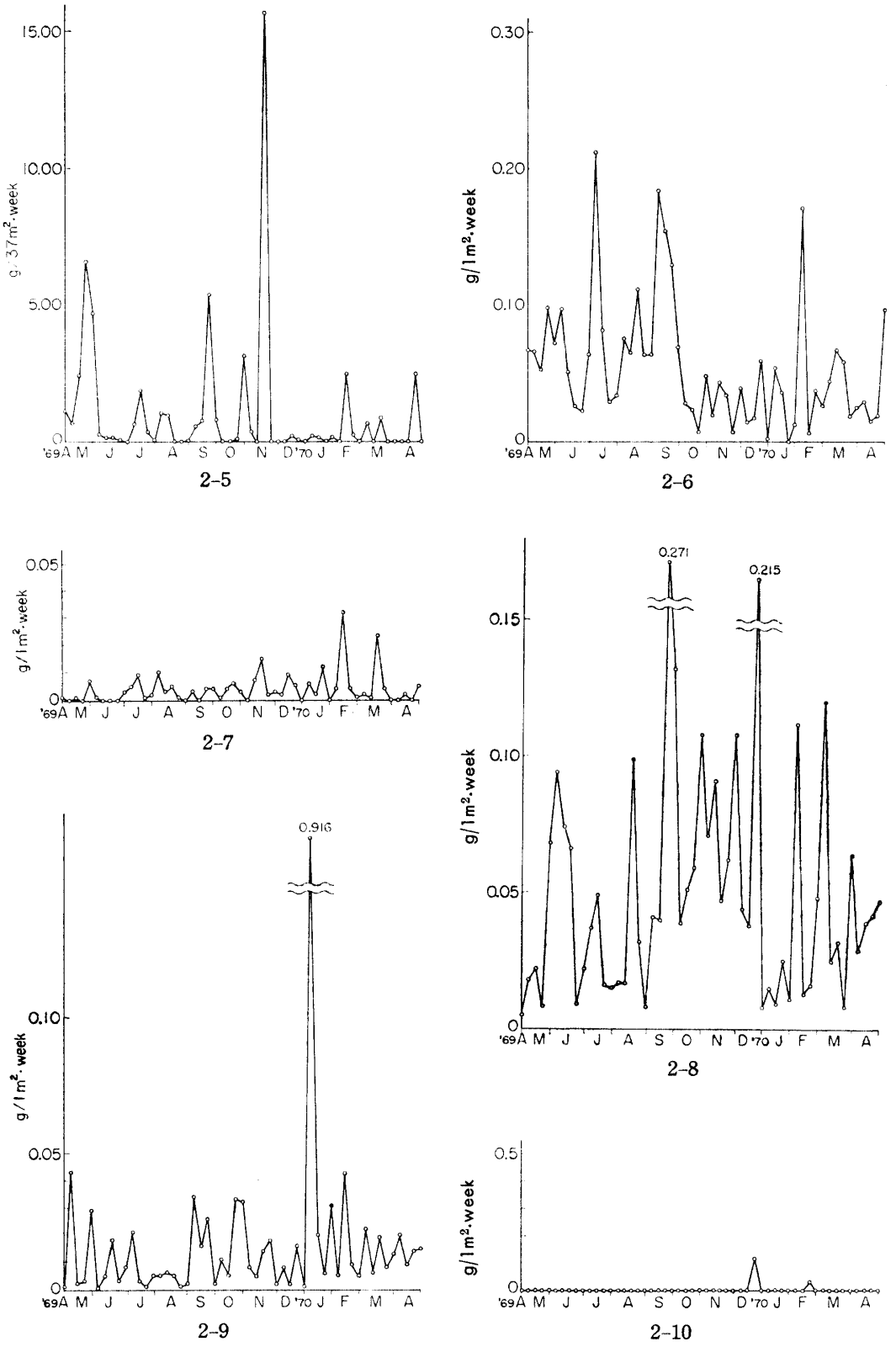
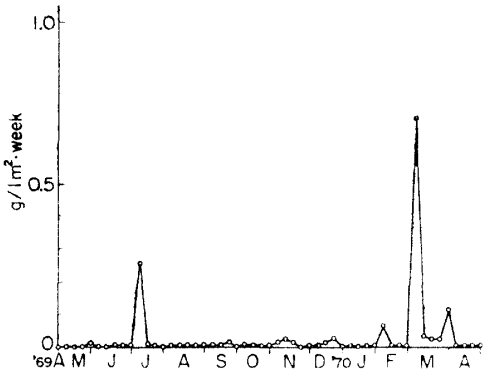


Fig. 2-5~10 Weekly amount of various kind of litter fall for one year at 1 ha-plot. Further notice, see text.



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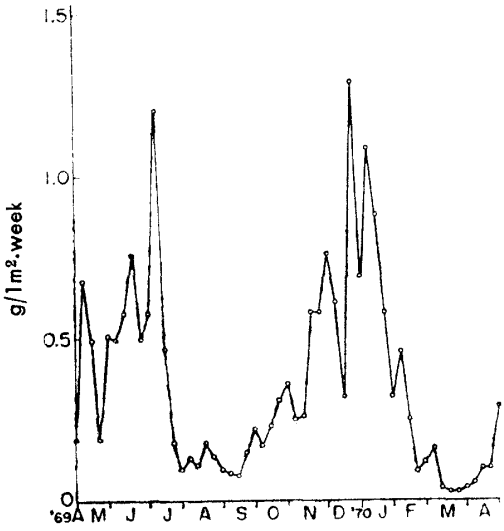

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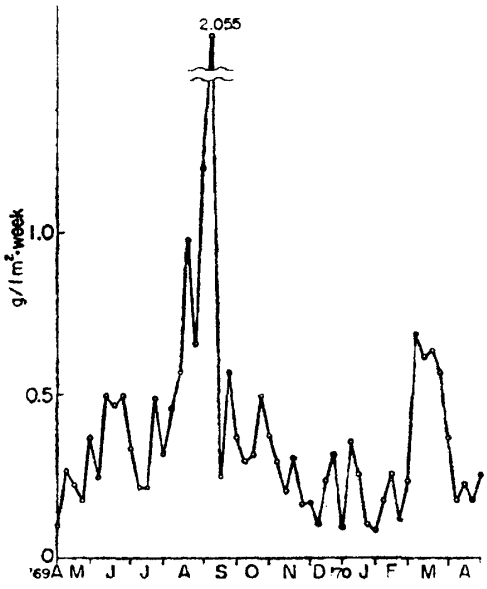

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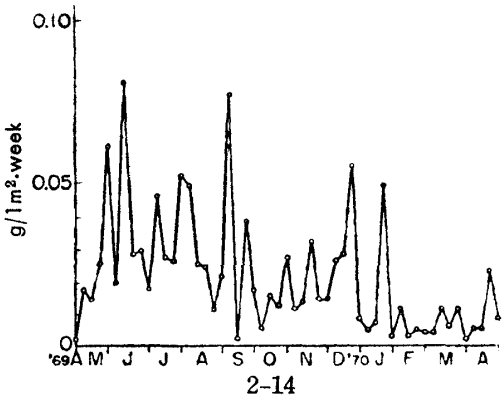

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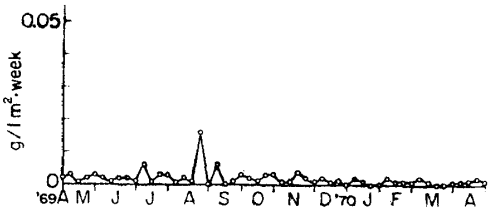

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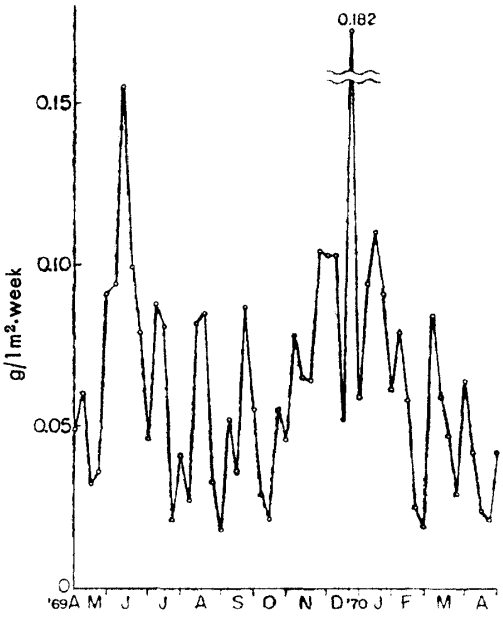


2-16

Fig. 2-11～16 Weekly amount of various kind of litter fall for one year at 1 ha-plot. Further notice, see text.

litter fall during the dry season than during the rainy season.

(15) Insect-litter (Fig. 2-15): No special tendency is shown except a small maximum point on the 27th August. Correlated with the insect feces litter, insect activity is estimated to be at a minimum during February to April and at a maximum in the dry period.

(16) Other litter (Fig. 2-16) "Other" means the litter which could not be placed in any of the above-mentioned categories mainly because the original shapes had been destroyed. The fluctuation shows two peaks, one is on the 11th June and another is on the 2nd December; other peaks are arbitrarily distributed.

As mentioned above, each component has its pattern of fluctuation throughout the year. This investigation, which was carried out for 20 months in all, is not adequate enough to conclude that there is any definite pattern of fluctuation, because the yearly variation in litter fall measurement is supposed to be very high, as stated in Saito (1972). These patterns, however, could be worth describing as one case study of tropical montane forest in West Java. To examine further information, each components will be divided further into species units as described below.

3. Leaf litter

Of the various kinds of leaf litter, those whose species name could be identified were divided into 5 groups, that is, (1) trees (normally reaching higher than 10 m in height), (2) shrubs, (3) herbs, (4) woody climbers and (5) epiphytes. Orchids, ferns and fern allies were seperately treated. Fig. 3 shows the percentage diagram for each groups. It can be clearly recognized that tree species occupy the overwhelmingly dominant position with 74% at the minimum and 96% at the maximum.

Epiphytes and climbers appear rather in larger quantites during the dry season, rather than the rainy season. On the 17th September, which is in the latter part of the dry season, they show their greatest percentage. Herbs are very few and shrubs constantly occur throughout the year.

Detailed features of each group are as follows:

(1) Tree species

Among the various kinds of leaf litter, 53 tree species (species which can reach more than 10 m in height normally) were enumerated (Table 2). Of those, *Platea latifolia* is the largest in relative dominance at 25.3% and second is *Castanopsis javanica* (14.1%), followed by *Vernonia arborea* (10.3%). Other species which are dominant in this plot such as *Persea rimosa, Schima wallichii, Lithocarpus rotundatus* also account for a considerable proportion of the litter. Species abundance by number each week shows a smooth movement throughout the year, that is, the highest number is 33 species on the 7th May 1969 and the minimum is 18 on the 18th February 1970. This fact must have been caused by the smaller number of litter traps, since some were stolen at about this time of the year. Lost traps were re-set on the forest floor after a few weeks and the errors caused there by were corrected.

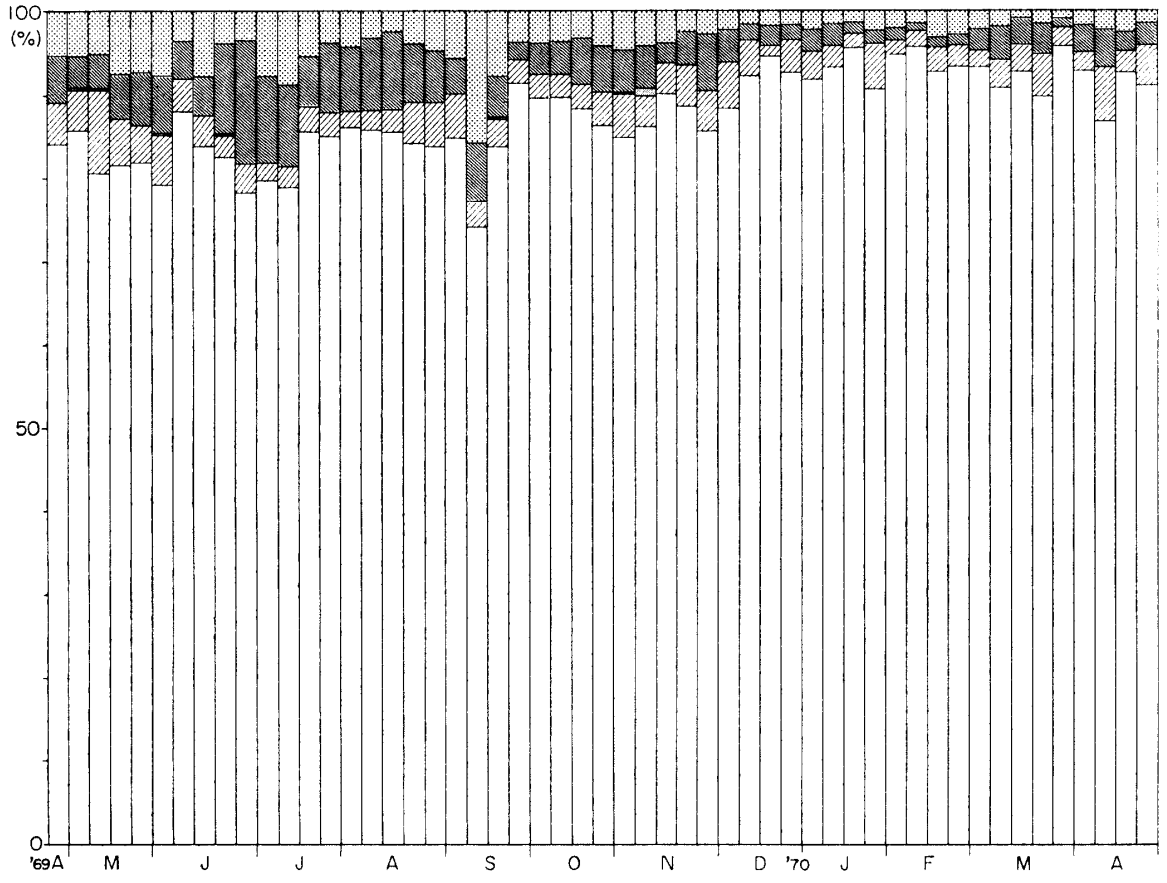


Fig. 3 Seasonal change of identified leaf fall. Ferns, fern allies and orchids are not included.

(a) Fagaceae: Both *Castanopsis* species show the same pattern as indicated in Fig. 4, exhibiting a rather clear leaf fall season after the dry season and in the middle of the rainy season, although *C. javanica* litter-fall is much greater than *C. argentea*.

Among *Lithocarpus* species, *L. pseudomoluccus* and *L. indutus* show the same pattern having a peak from January to April, while *L. rotundatus* has its highest value on July 9th, that is at the beginning of the dry season. *L. elegans* seems to have three peaks, that is, before the dry season, just after of dry season, and at the end of April.

Among 6 species of Fagaceae, *Castanopsis javanica* has the largest proportion of litter and *Lithocarpus rotundatus* comes next. Six species of Fagaceae are drawn on the weekly percentage diagram. (Fig. 5). The changing pattern of each species is very clearly indicated, that is *Castanopsis javanica* shows its lowest percentage in May and June, and its highest

Table 2 List of leaf-fall in tree species. Abundance is the frequency of appearance within 53 weeks. Relative dominance is the percentage of total litter amount

Species	Abundance per 53 weeks	Relative dominance %
Platea latifolia Bl.	53	25.285
Castanopsis javanica (Bl.) DC.	53	14.118
Vernonia arborea Buch.-Ham.	53	10.252
Prunus arborea (Bl.) Kalkman	53	9.591
Schima wallichii (DC.) Korth ssp. noronhae (Reinw. ex Bl.) Bloembergen	53	8.463
Persea rimosa (Bl.) Kosterm.	53	7.105
Flacourtia rukam Z. & M.	53	2.098
Symplocos fasciculata Zoll.	53	0.266
Engelhardia spicata Lech. ex Bl.	52	3.074
Decaspermum fruticosum var. polymorphum (Bl.) Bakh. f.	52	1.920
Glochidion macrocarpum Bl.	52	1.013
Polyosma integrifolia Bl.	51	1.014
Laplacea integerrima Miq.	49	1.900
Saurauia pendula Bl.	48	1.117
Astronia spectabilis Bl.	48	0.781
Litsea resinosa Bl.	48	0.509
Lithocarpus pseudomoluccus (Bl.) Rehd.	47	0.597
Turpinia sphaerocarpa Hassk.	47	0.448
Lithocarpus rotundatus (Bl.) A. Camus	46	6.280
Castanopsis argentea (Bl.) DC.	46	0.967
Lithocarpus elegans (Bl.) Hatus. ex Soepadmo	45	0.624
Meliosma nervosa K. & V.	43	0.509
Antidesma tetrandrum Bl.	43	0.430
Macropanax dispermus (Bl.) O.K.	43	0.154
Tarenna fragrans (Bl.) K. & V.	42	0.226
Syzygium rostratum (Bl.) DC.	41	0.273
Syzygium antisepticum (Bl.) Merry & Perry	40	0.031
Litsea mappacea (Bl.) Boerl.	28	0.110
Lithocarpus indutus (Bl.) Rehd.	26	0.554
Cinnamomum sintoc Bl.	23	0.072
Pygeum arboreum (Bl.) Endl. ex F. v. M.	11	0.081
Podocarpus imbricatus Bl.	8	0.015
Acronodia punctata Bl.	7	0.024
Macaranga rhizinoides (Bl.) M. A.	5	0.056
Manglietia glauca Bl.	3	0.012
Ficus ribes Reinw. ex Bl.	3	0.004
Itea macrophylla Wall.	3	0.002
Ficus sp.	2	0.003
Rapanea sp.	2	0.0004
Neonauclea obtusa (Bl.) Merr.	1	0.003
Litsea sp.	1	0.003
Polyosma sp.	1	0.003
Meliosma sp.	1	0.002
Mischocarpus fuscescens Bl.	1	0.002
Apodytes cambodiana Pierre	1	0.002
Antidesma sp.	1	0.002
Brassaiopsis glomerulata (Bl.) Regel	1	0.001
Helicia serrata (R. Br.) Bl.	1	0.001
Engelhardia sp.	1	0.001
Mastixia trichotoma Bl.	1	0.001
Glochidion rubrum Bl.	1	0.001

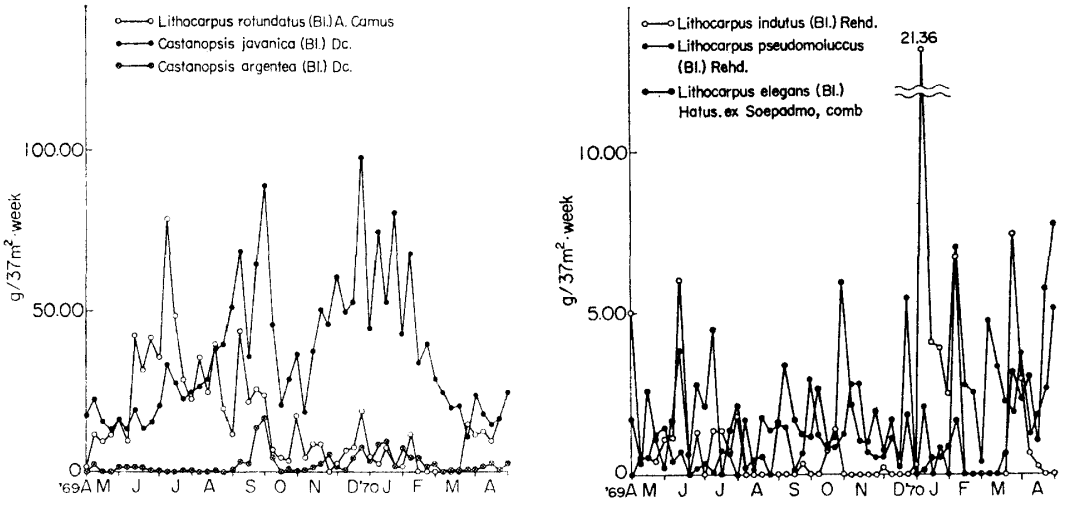


Fig. 4 Seasonal fluctuation of Fagaceae

percentage during the rainy season, whereas *Lithocarpus rotundatus* shows the converse trend. *Lithocarpus indutus* and *L. pseudomoluccus* resemble *Castanopsis javanica* more. Combining all six species, fluctuation of leaf litter in the Fagaceae exhibits two clear peaks as shown in Fig. 6.

(b) Theaceae (Figures for the main species mentioned below are given in the Appedix):

Schima wallichii indicates a very clear peak around the 20th August, that is in the middle of the dry season. This species is supposed to be typical, as it sheds leaves during the dry period, creating this peak, constant leaf fall occurs throughout the year, although the amount is much smaller than in the dry season.

(c) *Vernonia arborea*: This species shows no distinct peak, and a distinct drop appeared from the 11th February until the 25th February, coinciding with the middle of the rainy season.

(d) *Lauraceae*: *Persea rimosa* starts to increase its proportion of the litter from the 30th July and reaches a maximum on the 20th August, that is in the middle of the dry season, decreasing thereafter until the 17th September, and rising again to a new peak on the 22nd October, that is in the rather low-rainfall month. This species maybe concluded to be a dry season type. *Litsea resinosa* and *Cinnamomum sintoc* also show a similar pattern, although not so distinct as the above. Others, like *Listea mappacea* and *L. macrophylla* have no such clear tendency.

(e) *Engelhardia spicata*: This species shows a very clear peak on the 18th March. This is a typical species whose leaf-fall occur in the latter part of the rainy season.

(f) *Escalloniaceae*: *Polyosma ilicifolia* shows its highest peak on the 10th September, which indicates a very clear dry-season type. On the other hand, the position of *Polyosma integrifolia* can not be clearly determined, and a more or less greater amount of litter-fall occurs

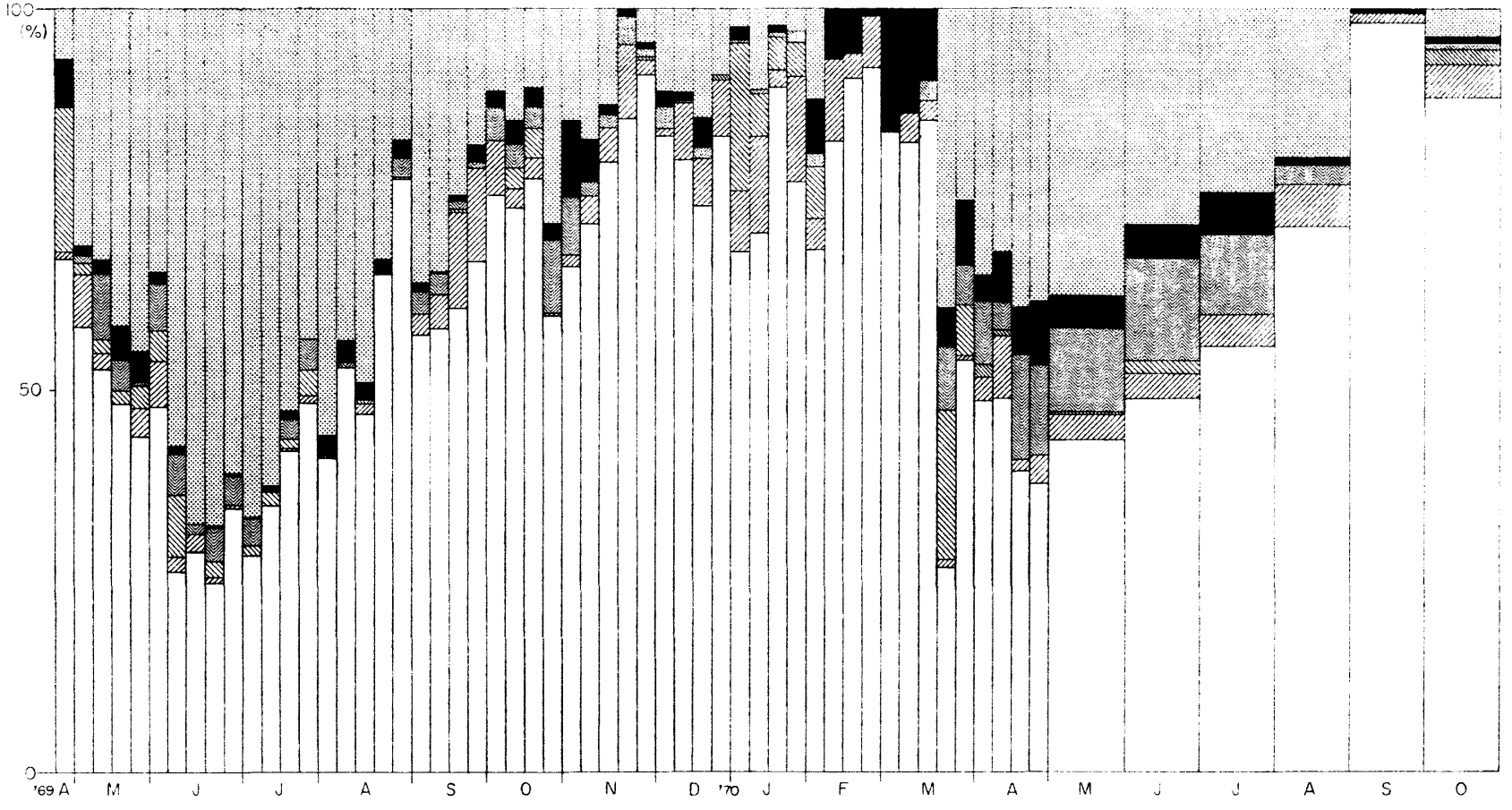


Fig. 5 Seasonal change of leaf-fall in 6 species of Fagaceae.

Castanopsis javanica
Castanopsis argentea
Lithocarpus indutus
Lithocarpus elegans
Lithocarpus pseudomoluccus
Lithocarpus rotundatus

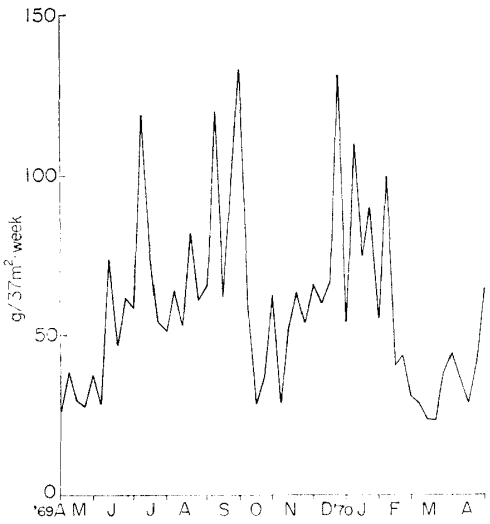


Fig. 6 Fluctuation of total leaf litter in 6 species of Fagaceae

during the first half of the rainy season.

(g) *Flacourtia rukam*: Leaf fall is highest on the 4th March and in general, a larger amount can be seen during the latter half of the rainy season.

(h) *Decaspermum fruticosum*: This species shows its highest value on the 29th April and the period after the dry season has a rather larger amount. No fall occurred from the 18th February to the 4th March.

(i) *Symplocos fasciculata*: Three peaks could be recognized, that is, 10th September, 29th October and 3rd December, which means this species leaf-fall occur from the latter half of the dry season through to the first half of the rainy season.

(j) *Saurauiaceae*: This lower layer species shows a very arbitrary fluctuation. *Saurauia pendula* is at its highest on the 24th September and next on the 18th June. The drier season as well as the middle of rainy season show rather small amounts of litter. *S. reinwardtiana* also shows a very random movement throughout the year. More litter seems to fall in the drier season than in the former species, but less in the latter half of the rainy season.

Species mentioned above are the main components of the study area. Besides these species, there are a considerable number of species whose leaf-fall is not negligible despite the small number of tree. Among these, *Platea latifolia* and *Prunus arborea* occupy quite a large percentage of the whole litter. The former reaches its highest quantity around the 10th September and decreases between the 8th October and the 10th December, and repeats the increasing and decreasing cycle again after that. The latter species reaches its highest on the 24th December, and the next peak is on the 13th August, which indicates that the latter species leaf-fall occur one month earlier in the dry season than the former.

Other species which occupy a considerable proportion of the litter, such as *Astronia spectabilis, Antidesma tetrandrum, Syzygium antisepticum, Glochidion macrocarpum, Macropanax dispermus, Tarenna fragrans* and *Turpinia sphaerocarpa* do not exhibit any

clear tendecies, except *Laplacea integerrima* and *Meliosma nervosa,* the former reaches its highest peak on the 20th August and the next peak is at the end of October, which shows a dry type litter fall. The latter is concentrated during the latter half of the dry season and throughout the first half of the rainy season.

Other species, such as *Acronodia punctata, Antidesma* sp., *Apodytes cambodiana, Brassaiopsis glomerulata, Glochidion rubrum, Helicia serrata, Mischocarpus fuscescens, Neonauclea obtusa, Podocarpus imbricatus, Syzygium rostratum, Rapanea* sp., are too scarce to determine the weekly fluctuation of their leaf litter.

All in all, tree species whose canopy is distributed in the upper strata have a tendency to be more affected by the climatic change than trees in the lower strata. Micro climate under the canopy may have a more complicated cycle than the surrounding outer atmosphere of the forest.

(2) Shrubs

Table 3 is a list of shrub species whose fluctuation are as follows:

Ardisia fuliginosa: This species shows a higher degree of leaf fall on the 20th August, 10th September and 29th October, which are in the dry period of the year.

Saurauia blumiana: The tendency of this species is to more or less concentrate on April and June, and rather smaller amounts can be recognized on the 3rd and 24th September and on the 28th January.

Strobilanthes cernua: This indicates highest peak on 10th September.

Villebrunea rubescense: The highest peak appears on the 10th September and next on the 10th December. During the drier weeks of July and February, there is a smaller amount

Table 3 List of leaf-fall in shrub species

Species	Abundance per 53 weeks	Relative dominance %
Villebrunea rubescens (Bl.) Bl.	53	46.36
Saurauia reinwardtiana Bl.	53	19.59
Polyosma ilicifolia Bl.	50	15.12
Ardisia fuliginosa Bl.	47	5.77
Strobilanthes cernua Bl.	32	2.05
Saurauia blumiana Benn.	19	8.67
Lasianthus sp.	15	0.59
Acronychia laurifolia Bl.	10	0.33
Talauma candollii Bl.	9	0.59
Viburnum lutescens Bl.	7	0.26
Strobilanthes sp.	2	0.59
Geniostoma sp.	2	0.02
Polygala venenosa Juss. ex Poir.	1	0.06
Ficus montana Burm. f.	1	0.002

of litter. Other shrub species such as *Ficus montana, Geniostoma* sp, a species of *Lasianthaceae, Viburnum lutescens,* have such small amounts that they cannot be discussed here.

(3) Herbs

As the fence of the litter trap was not so high, the leaves of herbs were also found in it. They were, however, in very small quantites, so that the tendency of herb species such as *Begonia robusta, Elatostema* sp, and *Disporum chinense,* could not be decided. Six species are listed in Table 4.

Table 4 List of leaf-fall in herb species

Species	Abundance per 53 weeks	Relative dominance %
Elatostema sp.	2	16.29
Elatostema integrifolium (D. Don) Wedd.	1	70.29
Cyrtandra picta Bl.	1	9.27
Disporum chinense (Ker-Gawl.) O. K.	1	1.92
Begonia robusta Bl.	1	1.28
Amomum pseudo-foetens Val.	1	0.96

(4) Ferns

As shown in Table 5, fern species are divided into 4 groups, of which epiphytic fern species are the largest in species numbers at 18, next 7 in terrestrial and 2 in tree ferns. The percentage of each group through the year is shown in Fig. 7, which indicates the overwhelmingly high percentage of epiphytic ferns. Tree ferns, however, sometimes shows high percentages at the end of May, on the 19th November, 11th February and 22nd April.

As the terrestrial ferns are naturally not so high, their occurence is controlled by the position of the litter traps. Figure 8 is a diagram of epiphytic ferns only, which were classified into 8 groups. The most abundant throughout the year are the *Polypodiaceae* in general, but the *Oleandra* group are concentrated in the period from 25th June to the 3rd September, 1969 and from August to October 1970, which coincides with the dry season. The *Lomariopsis* group occur mainly from the 10th to the 24th September, that is at the end of the dry season. The *Elaphoglossum* group has several peaks during the year of which the 7th May and the 4th March to the 1st April are the most prominent, that is in the latter half of the rainy season. *Asplenium* appears on the 5th November in 1969 and in July and August in 1970. Although this genus occurs abundantly in this plot, it seems they retain their old leaves even after the new leaves come out. We encounter many of *Asplenium's* nest form in whose lower part old leaves lie one upon another. *Davallia* group appear constantly. Groups of *Crypsinus, Hymenophyllum* and *Lycopodium* are very scarce compared with the above-mentioned

Table 5 List of leaf-fall in ferns and fern allies

Species	Abundance per 53 weeks	Relative dominance %
Epiphytic ferns		
Polypodiaceae	48	16.58
Davallia sp.	39	4.72
Polypodium sp.	36	13.96
Oleandra musifolia (Bl.) Presl.	31	10.78
Lomariopsis spectabilis (Kunze) Mett.	19	6.44
Elaphoglossum callifolium (Bl.) Moore	11	3.93
Asplenium nidus L.	8	1.59
Crypsinus macrochasmus (Bak.) Copel.	7	1.54
Elaphoglossum sp.	6	1.52
Davallia trichomanoides Bl.	2	0.25
Hymenophyllum sp.	2	0.20
Asplenium sp.	2	0.08
Crypsinus enervis (Cov.) Copel.	1	0.38
Asplenium caudatum Forst.	1	0.08
Lomariopsis sp.	1	0.07
Hymenophyllum junghuhnii v.d.B.	1	0.04
Oleandra sp.	1	0.008
Terrestrial ferns		
Diplazium dilatatum Bl.	8	2.65
Diplazium sp.	3	0.63
Dryopteris sp.	2	0.04
Pteris sp.	1	0.21
Diplazium pallidum (Bl.) Moore	1	0.08
Didymochlaena truncatula J. Sm.	1	0.008
Oleandra neriiformis Cav.	1	0.004
Tree ferns		
Cyathea junghuhniana (Kunze) Copel.	35	21.56
Cyathea contaminans (Wall. ex Hook.) Copel.	6	0.95
Unidentified species	51	11.68

genera and no special tendency can be detected. From a list of all fern and fern allies species found in the litter trap, the most abundant are unknown species of *Polypodiaceae,* which account for 16.6% of the relative dominance. Second are *Davallia* sp. followed by *Polypodium* sp. and *Cyathea junghuhniana,* which account for the largest number in the relative dominance. Unknown species appear as 11.7% in relative dominance. Among all the species, litter-fall trends could not recognized clearly with the single exception of *Oleandra musifolia,* which shows a rather larger anount of litter-fall during the dry period, even though it is constantly falling until the middle of February, and indeed during the end of the

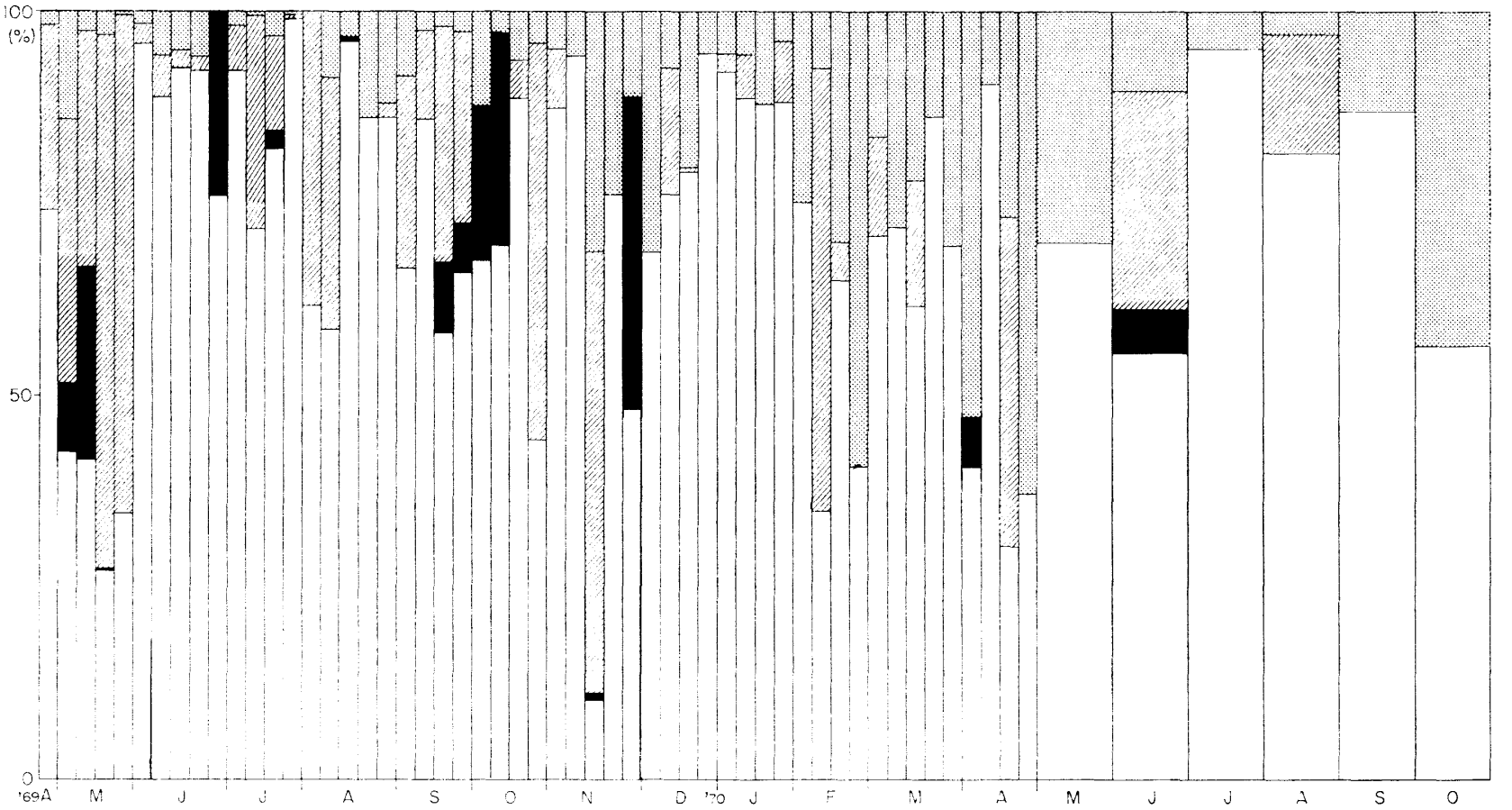


Fig. 7 Seasonal change of leaf-fall in ferns and fern allies

Epiphytic ferns
Tree ferns
Terrestrial ferns
Unidentified ferns

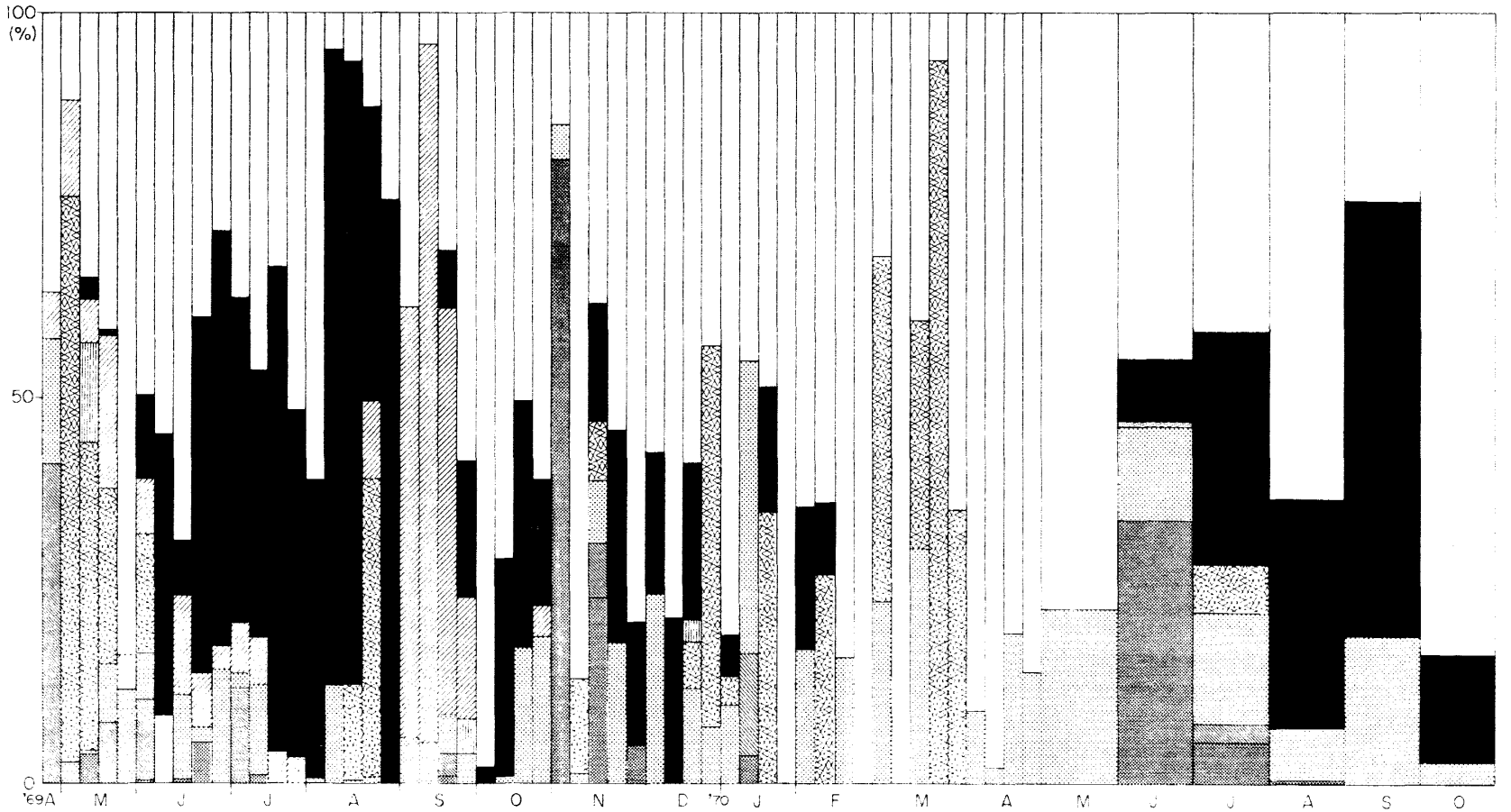


Fig. 8 Seasonal change of leaf-fall in epiphytic ferns

Asplenium group
Crypsinus group
Davallia group
Elaphoglossum group
Hymenophyllum group
Lomariopsis group
Lycopodium group
Oleandra group
Polypodiaceae group

rainy season no fall can be seen.

As the phenological information about ferns is very restricted, further discussion is impossible for the time being.

(5) Epiphytic Treelets

As indicated in Table 6, 23 species of this group were enumerated. Of those, *Vaccinium laurifolium var. ellipticum* appeared every week and accounted for 36% of the total of this group. The second is a species belongs to the *Loranthaceae* which account for 11% of the relative dominance. Although *Diplycosia heterophylla* account for 23% of the relative dominance, *Vaccinium laurifolium var. laurifolium* has a little more than the former. Abundance of the species of this group is high from the top to the 12th, *Aeschynanthus horsfieldii*.

Almost all species belonging to this group lose leaves mainly from the dry season to the beginning of rainy season. The succession of species is as follows: *Vaccinium laurifolium var. ellipticum* appear at the beginning of the dry season and are followed by *Vaccinium*

Table 6 List of leaf-fall in epiphytic treelets

Species	Abundance per 53 weeks	Relative dominance %
Vaccinium laurifolium var. ellipticum (Bl.) Sleum.	53	36.00
Loranthaceae	48	10.91
Diplycosia heterophylla Bl.	47	22.72
Ficus deltoidea Jack	47	1.23
Vaccinium lucidum (Bl.) Miq.	45	3.70
Ficus sinuata ssp. cuspidata (Reinw. ex Bl.) Corner	35	2.36
Medinilla laurifolia (Bl.) Bl.	34	1.47
Ilex spicata Bl.	32	4.62
Rhododendron javanicum (Bl.) Benn.	27	1.99
Vaccinium laurifolium var. laurifolium	24	23.36
Fagraea ceilanica Thunb.	24	5.04
Aeschynanthus horsfieldii R. Br.	24	0.49
Agalmyla parasitica (Lamk) O.K.	16	2.09
Medinilla verrucosa (Bl.) Bl.	10	0.57
Medinilla speciosa (Reinw. ex Bl.) Bl.	6	1.80
Ficus sinuata Thunb.	4	0.06
Aeschynanthus pulcher (Bl.) G. Don	3	0.02
Medinilla sp.	2	0.31
Ilex sp.	1	0.20
Aeschynanthus albidus (Bl.) Steud.	1	0.01
Aeschynanthus sp.	1	0.003
Dischidia nummularia R. Br. var. rhombifolia (Bl.) Bakh. f.	1	0.002
Vaccinium korthalsii Miq.	1	0.02

laurifolium var. laurifolium, Vaccinium lucidum, Loranthaceae, Rhododendron javanicum, Medinilla speciosa, Medinilla laurifolia, Ficus deltoidea, Fagraea ceilanica and *Diplycosia heterophylla*. During the transitional period between the dry and the wet season, *Agalmyla parasitica* and *Ilex spicata* predominate. Species of this group are characterized by a rather distinct patten of low litter-fall during the rainy season. Instability of the habitat may effect directly the seasonality of the species concerned.

(6) Woody Climbers and others

Although this group shows no such abundance as the epiphytic treelet group, the total species number is larger than 24. (Table 7) The important species are *Tetrastigma dichotomum* and *Schefflera lucescens*. They account for 57% of relative dominance and are followed by *Mussaenda frondosa, Schefflera scandens,* and *Embelia ribes*. *Schefflera lucescens, Tetrastigma dichotomum, Schefflera scandens, Embelia ribes, Ficus trichocarpa,* and *Piper baccatum* tend to be predominant during the dry season. On the other hand, *Actinidia callosa* and *Cissus adnata* litter falls more during the latter part of rainy season and *Kadsura*

Table 7 List of leaf-fall in woody climbers and others

Species	Abundance per 53 weeks	Relative dominance %
Piper cilibracteum DC.	37	1.36
Tetrastigma dichotomum (Bl.) Planch.	30	32.08
Schefflera lucescens (Bl.) Vig. var. rigida (Bl.) Bakh. f.	30	25.24
Mussaenda frondosa L.	30	9.07
Embelia ribes Burm. f.	30	5.53
Dendrotrophe umbellata (Bl.) Miq.	29	3.57
Schefflera scandens (Bl.) Vig.	28	8.27
Ficus sagittata Vahl	26	0.57
Alyxia reinwardti Bl.	25	3.04
Elaeagnus conferta Roxb.	24	1.40
Schefflera sp.	23	0.59
Ficus trichocarpa Bl.	22	1.97
Ficus lanata Bl.	20	1.37
Kadsura scandens (Bl.) Bl.	18	1.59
Actinidia callosa Lindl. var. callosa	17	0.71
Cissus adnata Roxb.	13	2.20
Piper baccatum Bl.	13	0.82
Smilax sp.	10	0.35
Rubia cordifolia L.	9	0.04
Embelia pergamacea DC.	3	0.11
Rubus moluccanus L.	2	0.02
Tetrastigma sp.	1	0.04
Smilax zeylanica L.	1	0.03
Elaeagnus sp.	1	0.02

scandens predominates during the middle of the rainy season. *Mussaenda frondosa, Dendrotrophe umbellata* and *Piper cilibracteum* leaves fall very smoothly throughout the year without any fluctuation.

(7) Orchids

As identification was difficult, only 5 species were named. *Bulbophyllum gibbosum* and *Bulbophyllum* species occur at the beginning of the dry season. *Cymbidium* species and *Cyperorchis rosea* appear in the dry season and *Eria* species during the middle of the rainy season.

Unidentified species show higher percentages during the dry season but considerable amounts still occur throughout the rainy season. Fluctuation of orchids as a whole may have similar patterns to the epiphytic ferns, although orchids survive the physiological change owing to their well-organized root system.

4. Weekly fluctuation of arboreal species

Leaves, flowers and fruits of the woody climber group, epiphytic treelet group, the orchid group and the epiphytic ferns (leaves only) are shown on the weekly histogram by their percentage. (Fig. 9) The most abundant is woody climbers and the epiphytic treelets are next. During the dry season, woody climbers account for more than 50% and consequently the number of epiphytic ferns is small, but extending over the beginning of the rainy season, epiphytic treelets usurp the primary position and during the middle of the rainy season, woody climbers, epiphytic treelets and epiphytic ferns are about equal and orchids too are larger than in the dry season.

5. Flower-fall

Named species whose flowers were found in the litter trap are shown in Table 8, which is classified into 6 groups, that is, 11 species in the tree group, 2 species in the shrub group, 4 species in the woody climber group, 7 species in the epiphytic treelet group, an unknown orchids and an unknown species group. Although the amount of unknown species accounted for a larger part of the litter (caused by the difficulty of identification of crushed flowers) the tendency of each group can be more or less distinguished in Fig. 10, which shows the weekly percentage of each group throughout the year.

Tree species show the largest proportion except for unknown species, and they show a high percentage around May, October-November 1969, and in April, May, June of 1970. The shrub group shows a high percentage on the 17th November 1969 and the 18th March 1970. Woody climber are not so distict except for around June-July 1969. Epiphytic treelet shows their highest level on the 13th April 1970. Other groups are very scarce.

Among these, the tree and shrub group are significant for phenological information. Fig. 11 is the seasonal changes of flowers in species of both groups. The most abundant species is *Platea latifolia,* which occurs from the 30th April-16th July 1969 and the 7th January-4th February, June, July, October, November 1970.

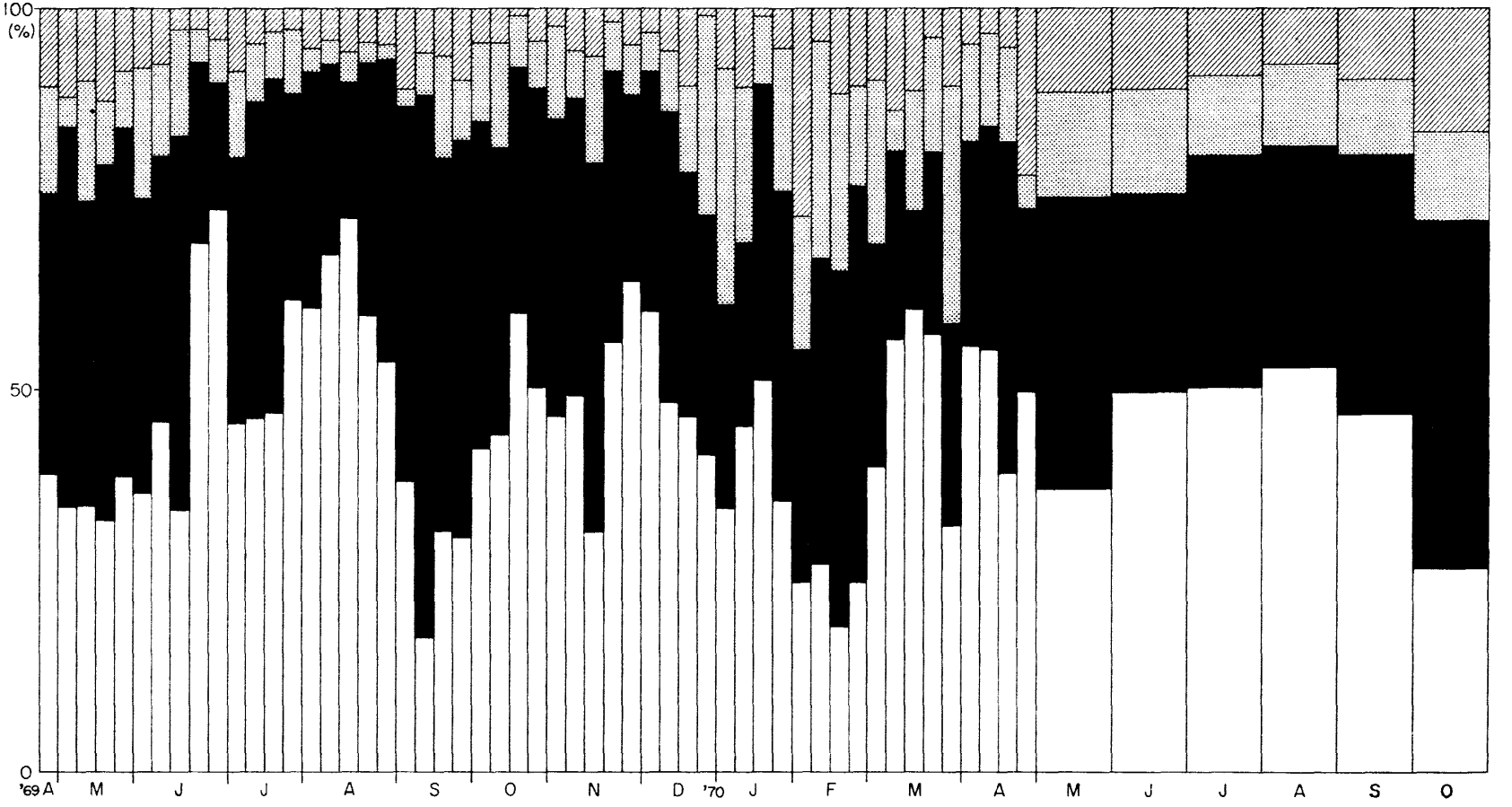


Fig. 9 Seasonal change of arboreal plants. Woody climbers, epiphytic treelets and orchids include leaves, flowers and fruits, whereas only leaves are included in epiphytic ferns.

Woody climbers
Epiphytic ferns
Epiphytic treelets
Orchids

Table 8 List of flower-fall species

Species	Abundance per 53 weeks	Relative dominance %
Trees		
Platea latifolia Bl.	21	13.14
Schima wallichii ssp. noronhae (Reinw. ex Bl.) Bloemb.	11	4.04
Saurauia pendula Bl.	10	0.45
Engelhardia spicata Lech. ex Bl.	7	0.28
Lithocarpus rotundatus (Bl.) A. Camus	3	1.02
Lithocarpus elegans (Bl.) Hatus. ex Soepadmo, comb.	2	0.64
Castanopsis javanica (Bl.) DC.	2	0.08
Podocarpus imbricatus Bl.	1	0.05
Vernonia arborea Buch.-Ham.	1	0.02
Tarenna fragrans (Bl.) K. & V.	1	0.01
Eurya acuminata DC.	1	0.003
Shrubs		
Saurauia reinwardtiana Bl.	15	0.57
Saurauia blumiana Benn.	11	0.53
Woody climbers		
Mussaenda frondosa L.	13	0.21
Piper cilibracteum DC.	2	0.04
Schefflera lucescens var. rigida (Bl.) Bakh. f.	1	0.21
Kadsura scandens (Bl.) Bl.	1	0.02
Epiphytic treelets		
Loranthaceae	4	0.21
Vaccinium laurifolium (Bl.) Miq.	4	0.08
Agalmyla parasitica (Lamk) O.K.	4	0.06
Rhododendron javanicum (Bl.) Benn.	1	0.02
Fagraea sp.	1	0.01
Vaccinium lucidum (Bl.) Miq.	1	0.007
Aeschynanthus horsfieldii R. Br.	1	0.001
Orchidaceae	2	0.02
Unidentified species	53	78.27

Schima wallichii appears on the 15th October-10th December 1969 and in August and September 1970. Within the *Fagaceae, Castanopsis javanica* appears on the 20th August, 12th November 1969 and *Lithocarpus rotundatus* occurs at the beginning of April, followed by *Lithocarpus elegans* appearing in May and August 1970.

Among the lower height species of *Saurauiaceae, Saurauia pendula* occurs in July, August, and *S. blumiana* from November 17th-3rd of December 1969 and on the 18th February and the 18th March 1970, and *S. reinwardtiana* occurs mainly in September through to the middle of October.

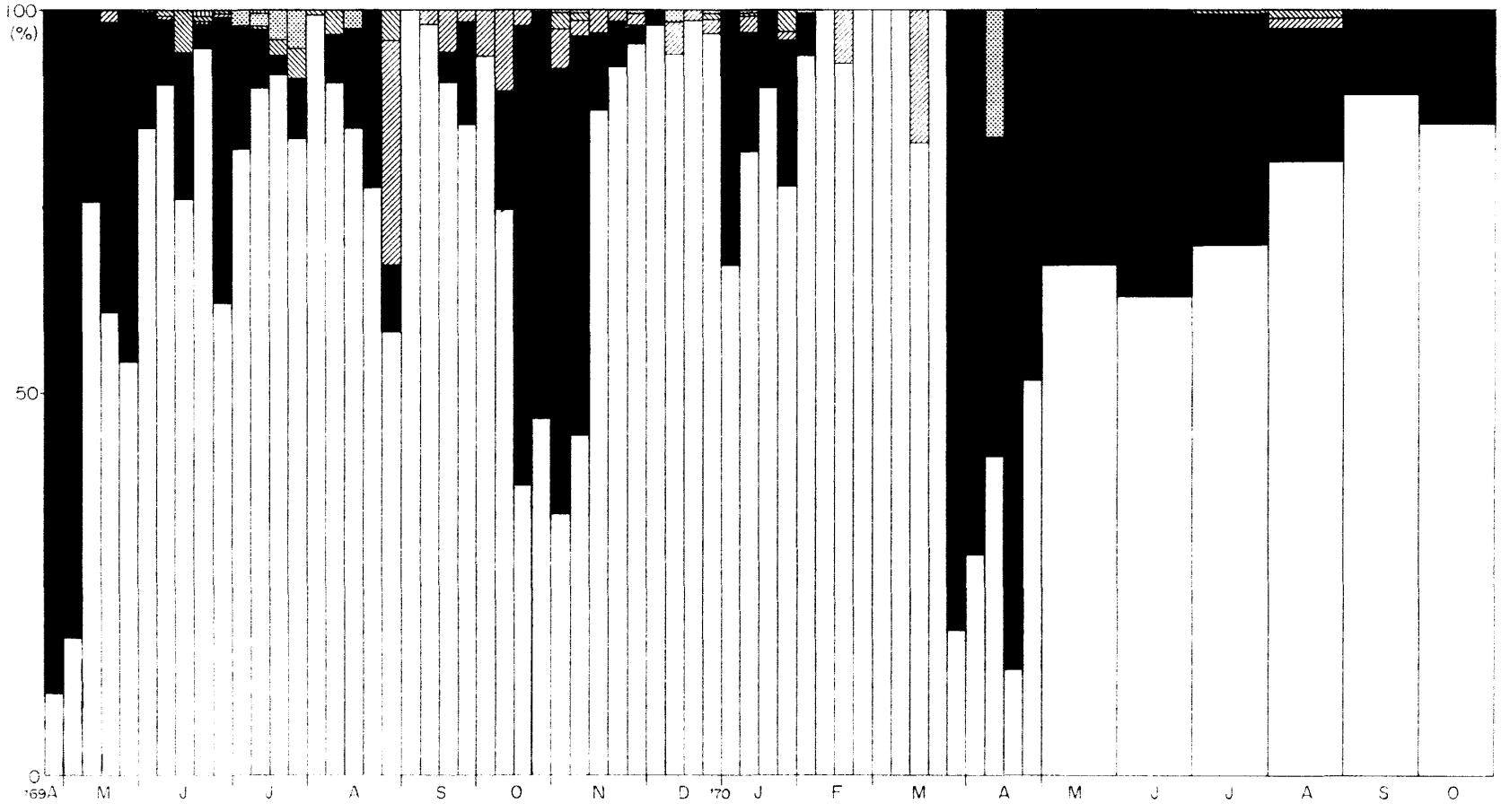


Fig. 10 Seasonal change of flower-fall in 6 group

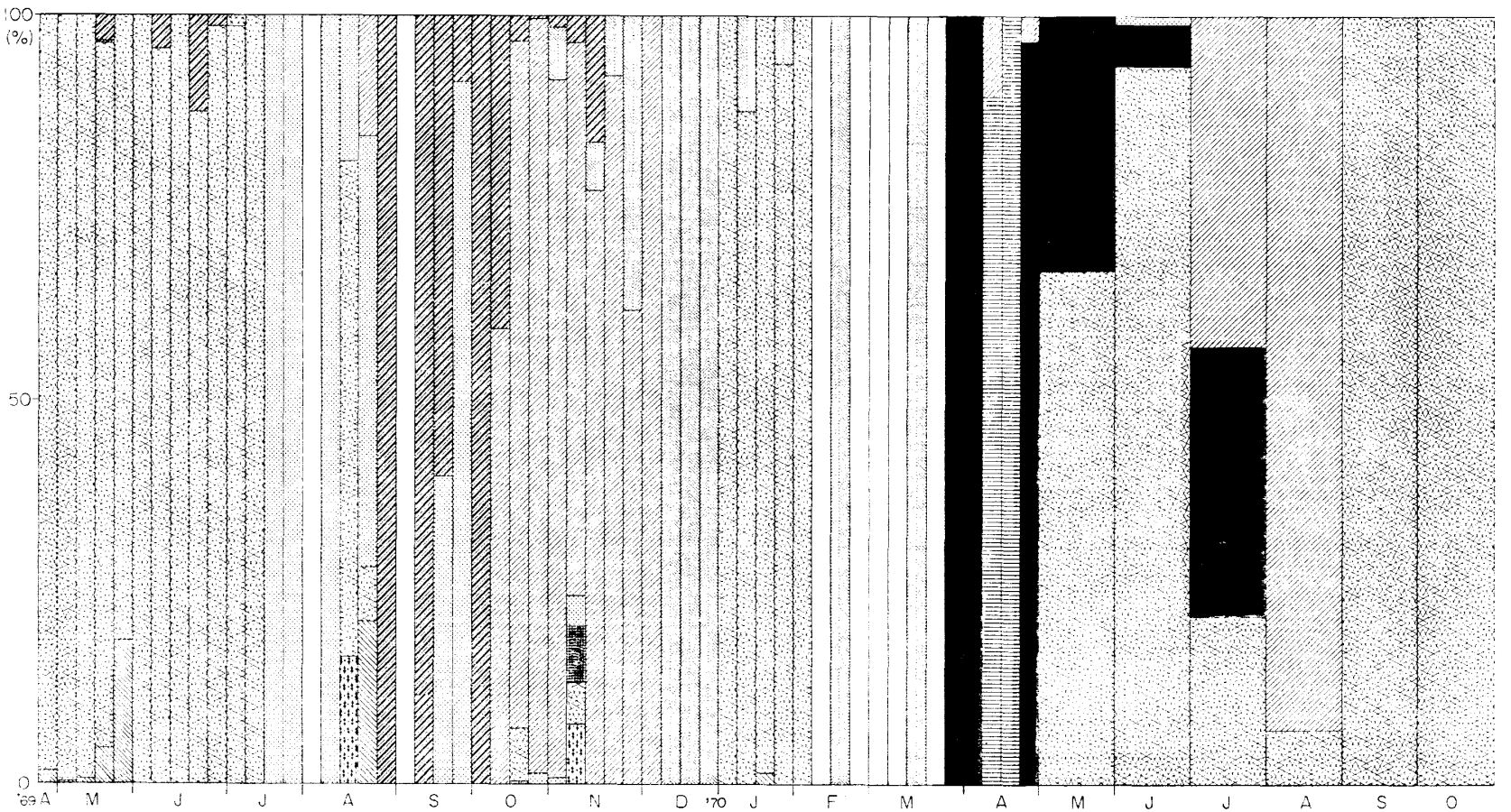


Fig. 11 Seasonal change of flower-fall in trees and shrubs

No flower period
Castanopsis javanica
Engelhardia spicata
Eurya acuminata
Platea latifolia
Podocarpus imbricatus
Lithocarpus rotundatus
Lithocarpus elegans
Saurauia pendula
Schima wallichii
Tarenna fragrans
Vernonia arborea
Saurauia blumiana
Saurauia reinwardtiana

According to this figure, coincidince of the flowering period among species does not occur so frequently except for a few seasons such as on the 12th November when 6 flowering species were counted. It may be said that the tree species of this plot are in bloom one by one the year round and some of them flower twice a year and others only once a year. Together with these community level studies, phenological observation of single marked trees can add more detailed information about species. As gathering of litter was carried out at monthly intervals, from May to November 1970, accuracy in classifing into species units was very doubtful due to the destruction of flower petals. It is desirable to collect flower samples at weekly intervals in future studies of litter production if we wish to know the seasonality of flowering in species units in more detail.

6. Fruit-fall

Among tree species, the fruits of 14 species were found during one and a half years, one shrub, 5 of both woody climbers and epiphytic treelets, and 1 of both orchids and palms as shown in Table 9. The most abundant species was *Schima wallichii* which accounted for 16.6% of total fruit. The second was *Castanopsis javanica* (5.6% relative dominance) followed by *Grochidion macrocarpum* (6.2%). Although the abundance of *Platea latifolia* is small, relative dominance is second because of a concentrated fall from 3rd-10th September. Compared with tree species, fruits of other groups are much fewer.

Fig. 12, indicating a weekly change of fruit-litter in the plot, shows the high percentage of tree species clearly. Among these, *Decaspermum fruticosum* fruits between the end of the rainy season and the beginning of the dry season, whereas *Grochidion macrocarpum* shows two peaks at the same season as the former, and during the middle of the rainy season one more small peak could be seen on the 22nd October. Except for *Schima wallichii, Castnopsis javanica,* and *Platea latifolia,* major species bear fruit once a year. The exceptions mentioned are probably due to the high percentage of individual occurence in this community. The period when the number of species was found to be largest was the 2nd July, when 8 species were counted, and the largest amount occurred on the 10th September, 1969. From 13th August until 10th September is the season of greatest fruit production. This period coincides more or less with the latter part of the dry season.

7. Short notice on phenology and regeneration

Although each component of litter fall was mentioned separately in the preceding chapter, combination of the three elements, viz, leaf-, flower- and fruit-fall is essential to learn about the phenological condition of this area.

In this chapter, the interrelationship of the three elements will be considered based on the 13 species which showed flowering and fruiting during the time of the survey. They are 8 species of tree (*Castanopsis javanica, Engelhardia spicata, Platea latifolia, Lithocarpus rotundatus, Schima wallichii, Tarenna fragrans, Vernonia arborea* and *Podocarpus imbricatus*), 1 species of shrub (*Saurauia blumiana*), 3 species of woody climber (*Kadsura*

Table 9 List of fruit-fall species

Species	Abundance per 53 weeks	Relative dominance %
Trees		
Schima wallichii ssp. noronhae (Reinw. ex Bl.) Bloemb.	42	16.58
Castanopsis javanica (Bl.) DC.	23	5.59
Grochidion macrocarpum Bl.	21	6.23
Platea latifolia Bl.	9	12.10
Decaspermum fruticosum var. polymorphum (Bl.) Bakh. f.	9	0.59
Vernonia arborea Buch.-Ham.	5	0.21
Engelhardia spicata Lech. ex. Bl.	5	0.05
Prunus arborea (Bl.) Kalkm.	4	0.15
Tarenna fragrans (Bl.) K. & V.	2	0.14
Lithocarpus rotundatus (Bl.) A. Camus	1	0.12
Flacourtia rukam Zoll. et Mor.	1	0.05
Antidesma tetrandrum Bl.	1	0.001
Shrubs		
Saurauia blumiana Benn.	1	0.005
Woody climbers		
Tetrastigma dichotomum (Bl.) Planch.	2	0.07
Schefflera lucescens var. rigida (Bl.) Bakh. f.	1	0.19
Mussaenda frondosa L.	1	0.007
Kadsura scandens (Bl.) Bl.	1	0.004
Epiphytic treelets		
Vaccinium lucidum (Bl.) Miq.	6	0.12
Diplycosia heterophylla Bl.	2	0.07
Fagraea ceilanica Thumb.	1	0.03
Ficus deltoidea Jack	1	0.02
Loranthaceae	1	0.01
Orchids		
Orchidaceae	5	0.03
Palms		
Pinanga coronata (Bl. ex Mart.) Bl.	3	0.20
Unidentified species	53	57.41

scandens, Mussaenda frondosa and *Schefflera lucescens var. rigida*), 2 epiphytes (a species of *Loranthaceae* and *Vaccinium lucidum*) and species of *Orchidaceae.*

Fig. 13 is a compound-figure for leaf-, flower- and fruit-fall time of 13 species throughout one year. According to this figure, the rather concentrated part can be recognized around the dry period especially for flower-fall, but the general trend is inclined to a random distribution. The tropical lowland has no season which causes such a clear peak of flowering

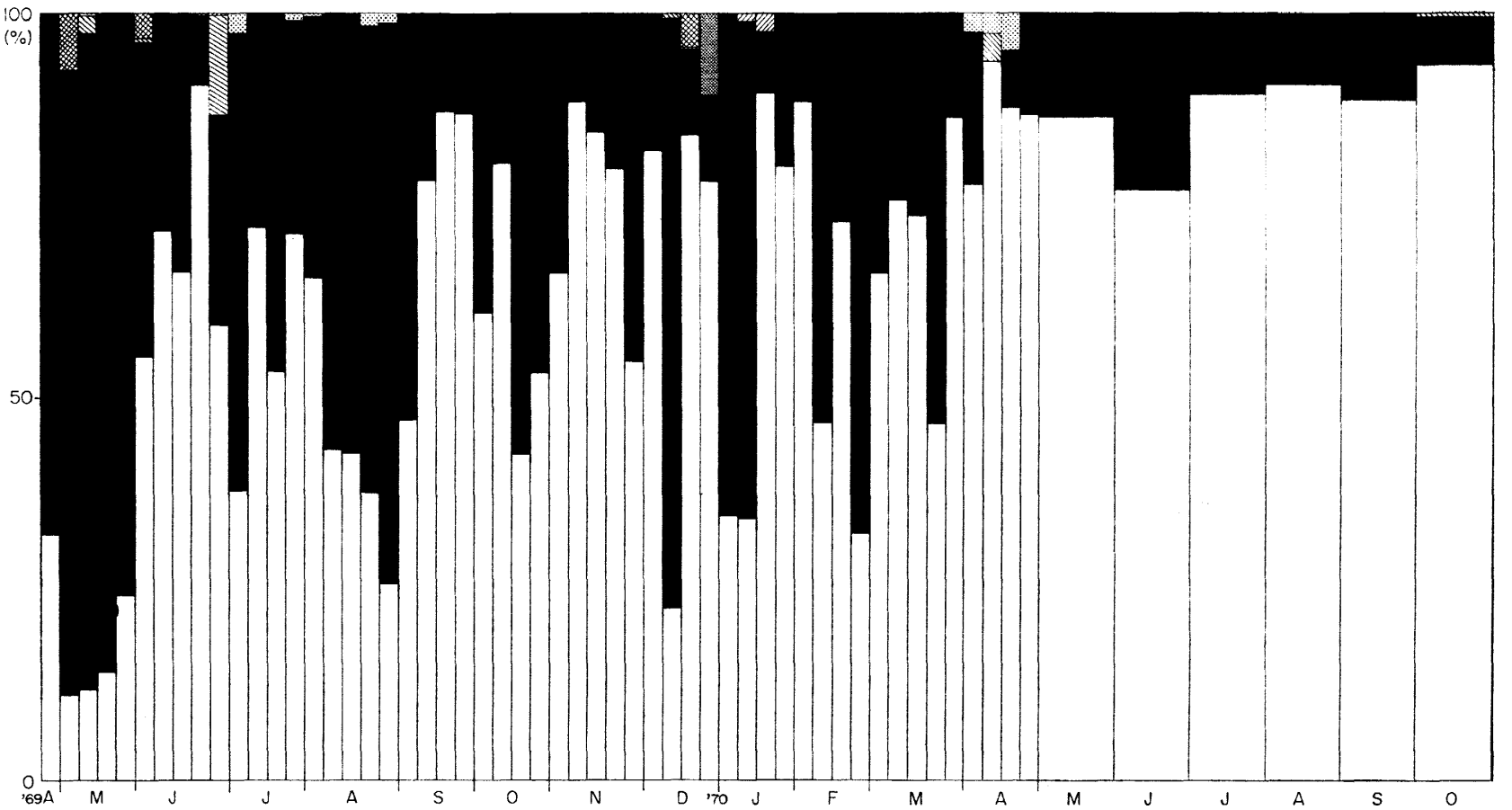


Fig. 12 Seasonal change of fruit-fall

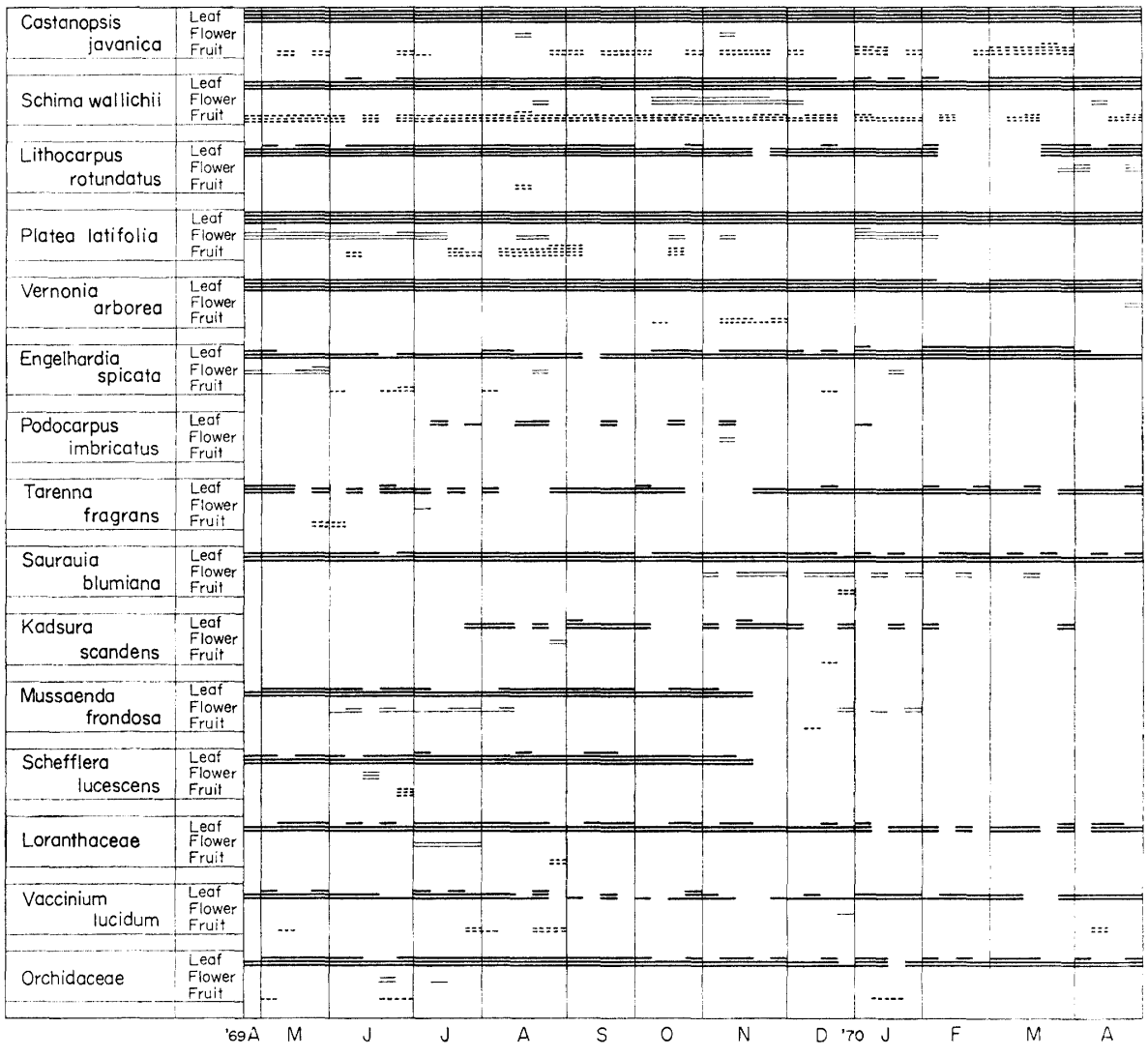
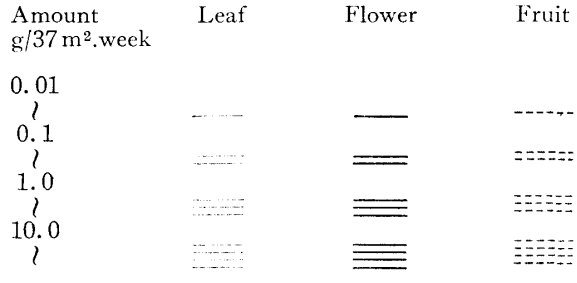


Fig. 13 Fluctuation of leaf, flower and fruit-fall in 13 species. Legend is below.



and fruiting as is commonly observed in the temperate climate zone. In this montane forest, a short dry spell exists which act on the flowering of some species as mentioned above. But, the general tendency is still inclined to the typical tropical pattern.

Table 10 is a summary of the leaf-fall type of the main species of trees and shrubs. Although the classification of each species is not very simple and many types can be recognized,

Table 10 Leaf-fall types among the main species of trees and shrubs in the 4 seasons. Each species is classified into 3 layers as used in the first report of this series.

	Dry season	First half of rainy season	Middle of rainy season	Latter half of rainy season
1st layer	Lithocarpus rotundatus	Cinnamomum sintoc	Castanopsis javanica	Engelhardia spicata
	Platea latifolia	Litsea resinosa		Lithocarpus indutus
	Schima wallichii			Lithocarpus pseudomoluccus
	Vernonia arborea	Vernonia arborea	Vernonia arborea	Vernonia arborea
2nd layer	Litsea mappacea		Polyosma integrifolia	Decaspermum fruticosum
	Persea rimosa			Flacourtia rukam
	Polyosma ilicifolia			
	Laplacea integerrima	Laplacea integerrima		
3rd layer	Strobilanthes cernua	Meliosma nervosa	Castanopsis argentea	Lithocarpus elegans
		Symplocos fasciculata		Saurauia blumiana
	Villebrunea rubescens	Villebrunea rubescens		
	Prunus arborea		Prunus arborea	
	Ardisia fuliginosa	Ardisia fuliginosa	Ardisia fuliginosa	Ardisia fuliginosa
	Saurauia pendula	Saurauia pendula	Saurauia pendula	Saurauia pendula
	Saurauia reinwardtiana	Saurauia reinwardtiana	Saurauia reinwardtiana	Saurauia reinwardtiana
	Turpinia sphaerocarpa	Turpinia sphaerocarpa	Turpinia sphaerocarpa	Turpinia sphaerocarpa

it is clear that each species shows its own peculiar type of leaf-fall on each season.

Both in the dry season and in the latter half of the rainy season, 7 species appear and they mainly belong to the 1st layer. *Laplacea integerrima, Villebrunea rubescens* and *Prunus arborea* are the bimodal type and the former two species have larger amounts of leaf-fall in the dry season whereas the last species shows the reverse trend. Among 5 species of the non-seasonal type, four species (*Ardisia fuliginosa, Saurauia pendula, Saurauia reinwardtiana* and *Turpinia sphaerocarpa*) are dominant in the 3rd layer of this forest. As mentioned in the preceding chapter, it can be said that the species of the 1st layer indicate a clearer seasonality than the 2nd and 3rd layer species. *Vernonia arborea* is an exceptional case which exhibits no clear tendency despite being a 1st layer species.

As mentioned in the first report of this series (Yamada 1975), the floristic composition of this study area was made very complex by so many species and various life forms. We know now from this report that the phenological pattern of each species also exhibits very complicated structure compared with other forests of the non-tropical area. This diversity is the most distinctive feature of tropical forest.

Natural cycling of combinations of such multifarious factors maintain the forest environment in optimum condition.

The regeneration problem, which needs immediate attention especially in the tropics, could be connected with the above-mentioned litter study. Although very detailed studies

of seed-ecology, seed dispersal and germination capacity, have been carried out in temperate areas, for instance, in Japan by Tagawa (1969, 1973), Rim and Shidei (1974), Kanazawa (1975), we don't have such quantitative works for the tropics so far. As the study of phenology, litter fall and regeneration builds up a three-cornered basis for forest ecology, a careful and long term survey of each vertex is inevitable.

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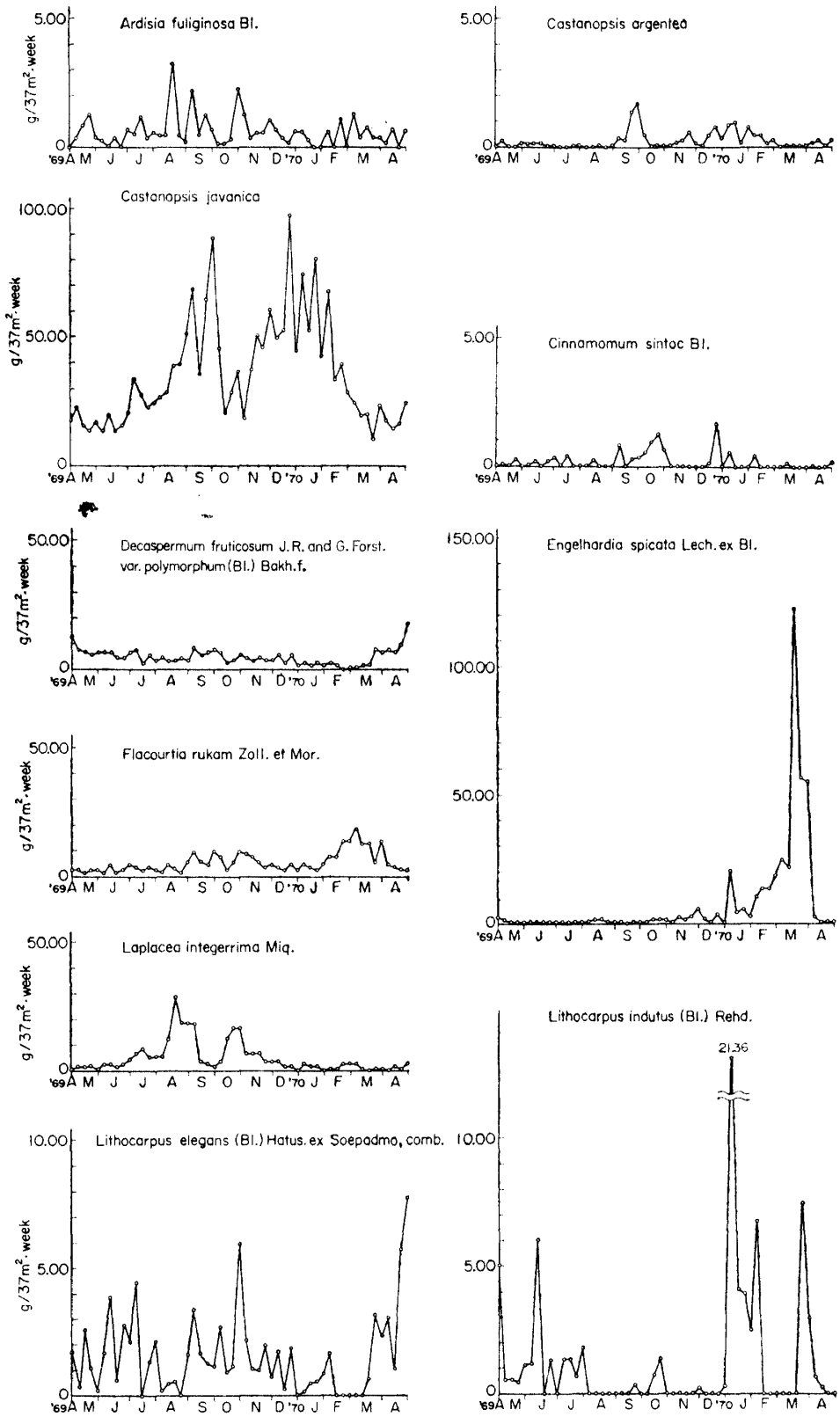
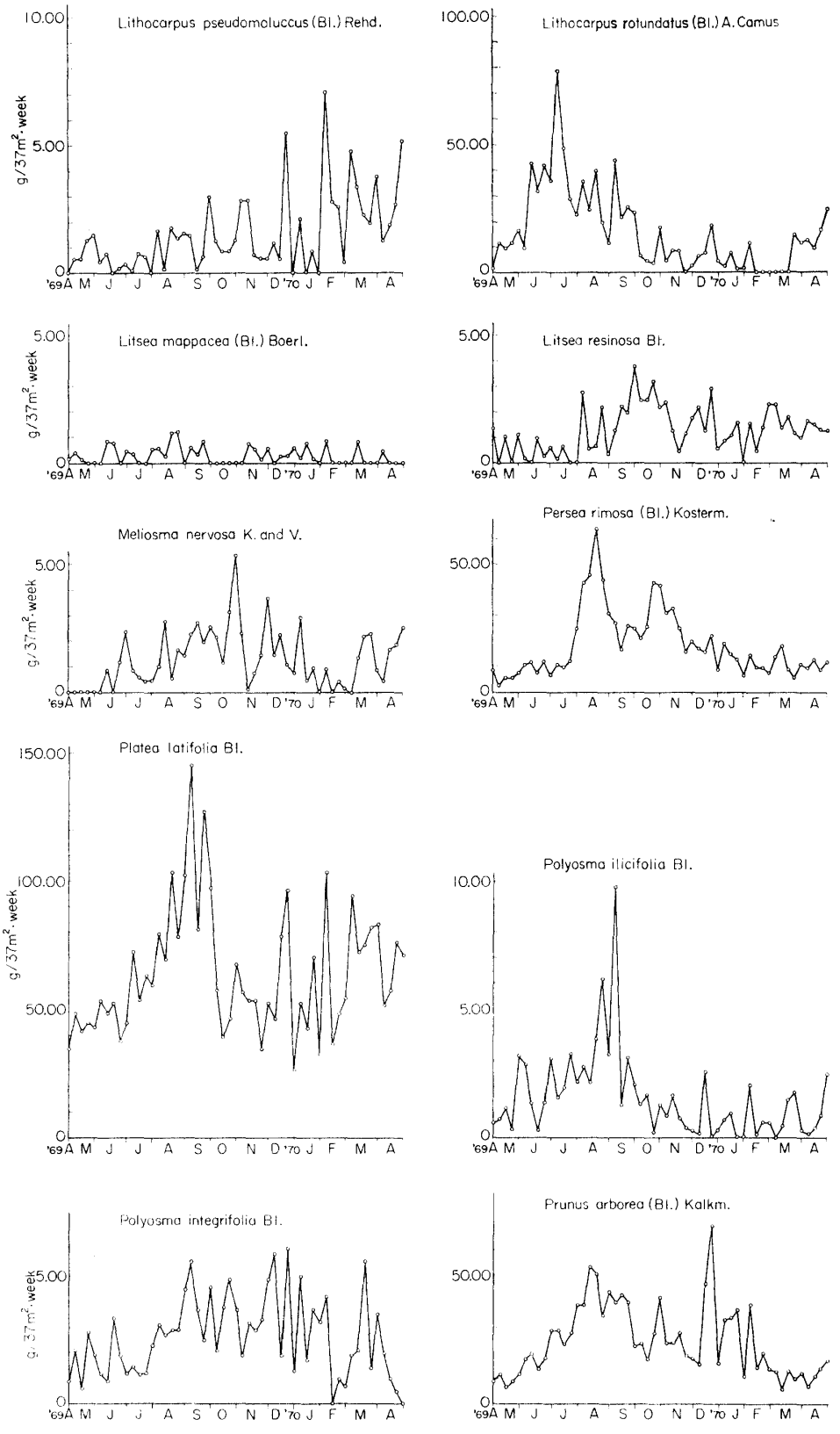
Appendix

Fluctuation figures of major species in 3 groups are shown below. Species arranged in alphabetical order.

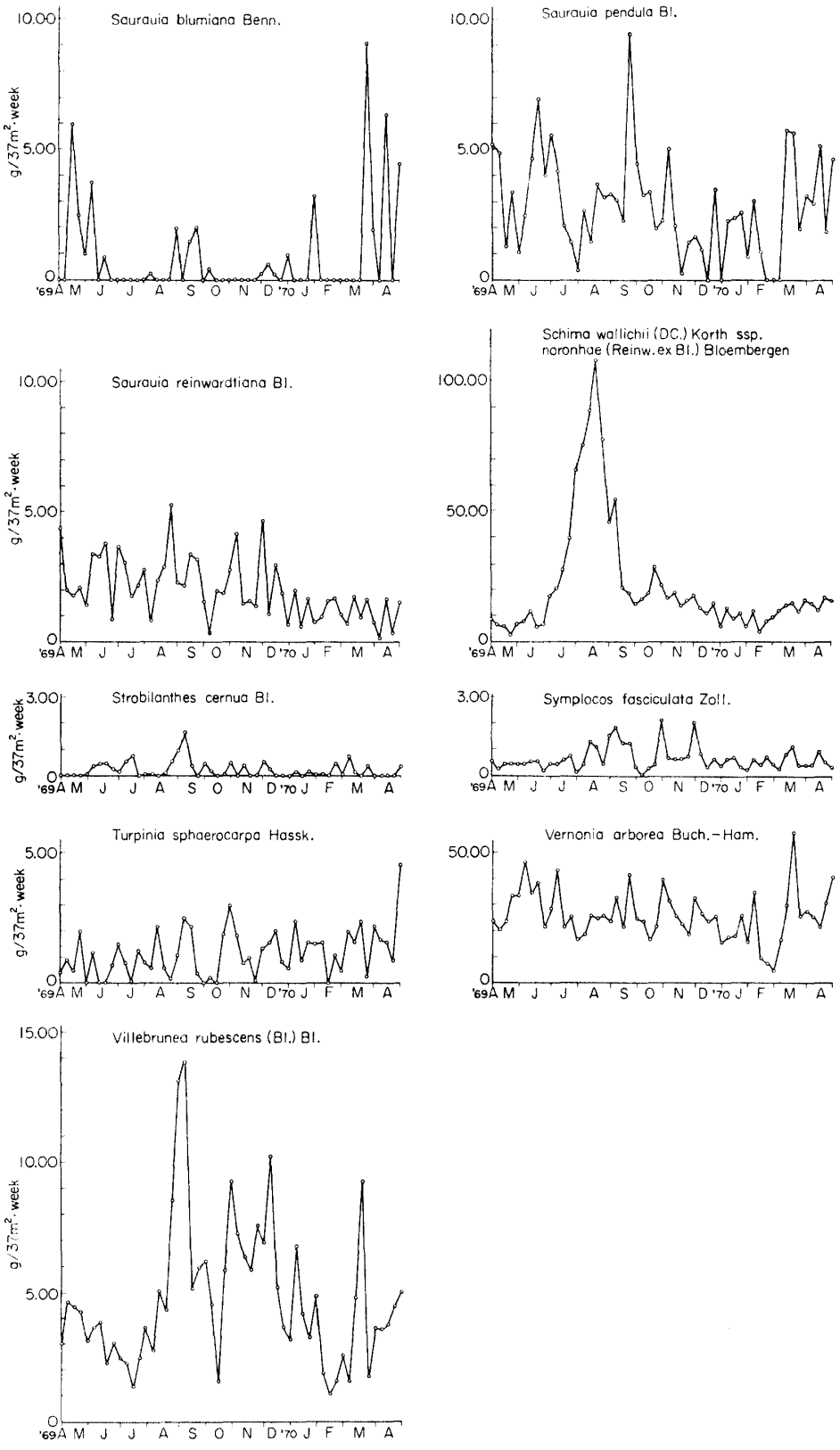
(1) Trees and shrubs
(2) Epiphytic treelets
(3) Woody climbers


Ardisia fuliginosa Bl.
Castanopsis argentea
Castanopsis javanica
Cinnamomum sintoc Bl.
Decaspermum fruticosum J.R. and G. Forst. var. polymorphum (Bl.) Bakh.f.
Engelhardia spicata Lech. ex Bl.
Flacourtia rukam Zoll. et Mor.
Laplacea integerrima Miq.
Lithocarpus indutus (Bl.) Rehd.
21.36
Lithocarpus elegans (Bl.) Hatus. ex Soepadmo, comb.
g/37m²·week
'69A M J J A S O N D '70 J F M A

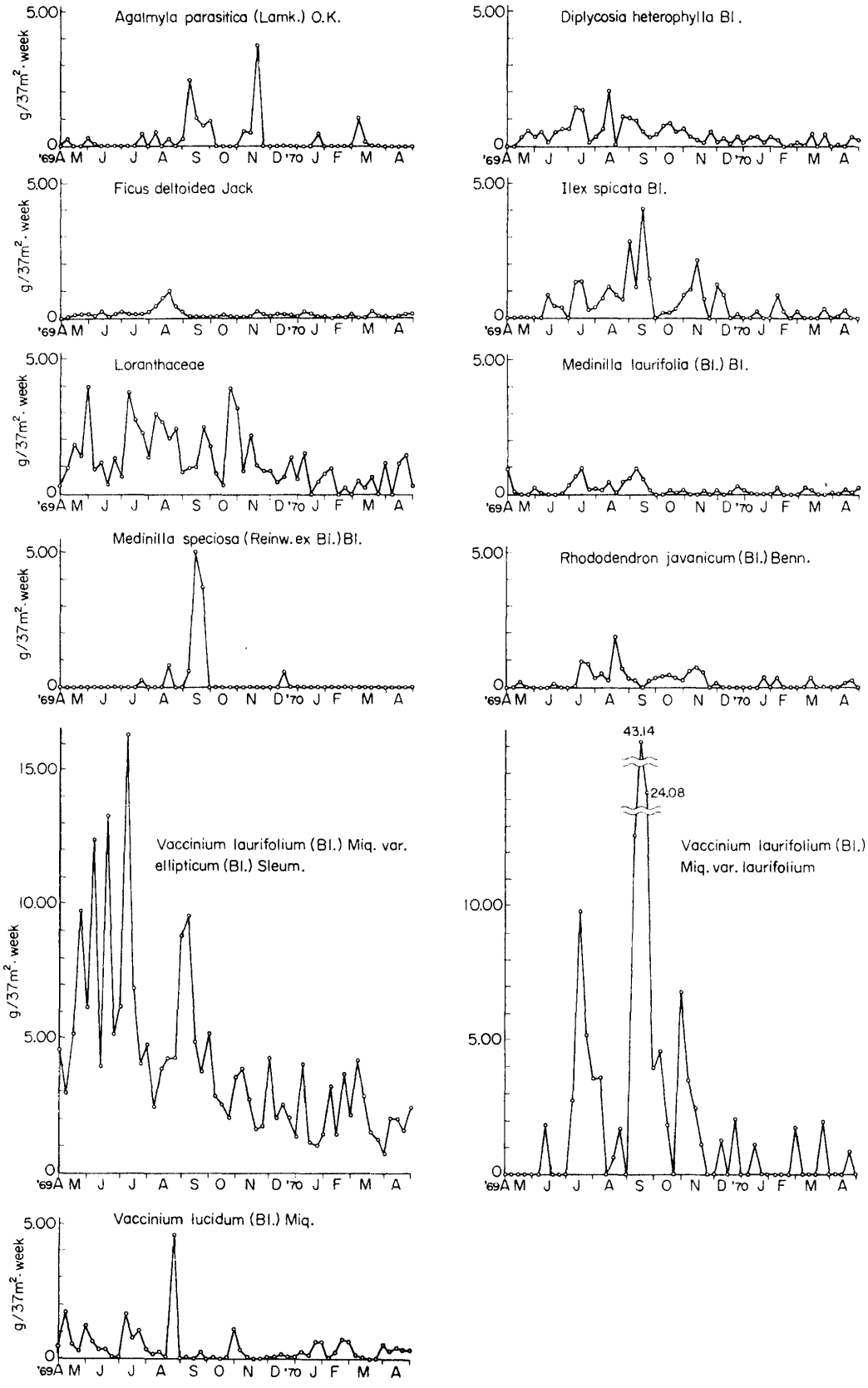
Appendix (1)′


Lithocarpus pseudomoluccus (Bl.) Rehd.
Lithocarpus rotundatus (Bl.) A. Camus
Litsea mappacea (Bl.) Boerl.
Litsea resinosa Bl.
Meliosma nervosa K. and V.
Persea rimosa (Bl.) Kosterm.
Platea latifolia Bl.
Polyosma ilicifolia Bl.
Polyosma integrifolia Bl.
Prunus arborea (Bl.) Kalkm.
g/37m²·week
'69A M J J A S O N D '70 J F M A

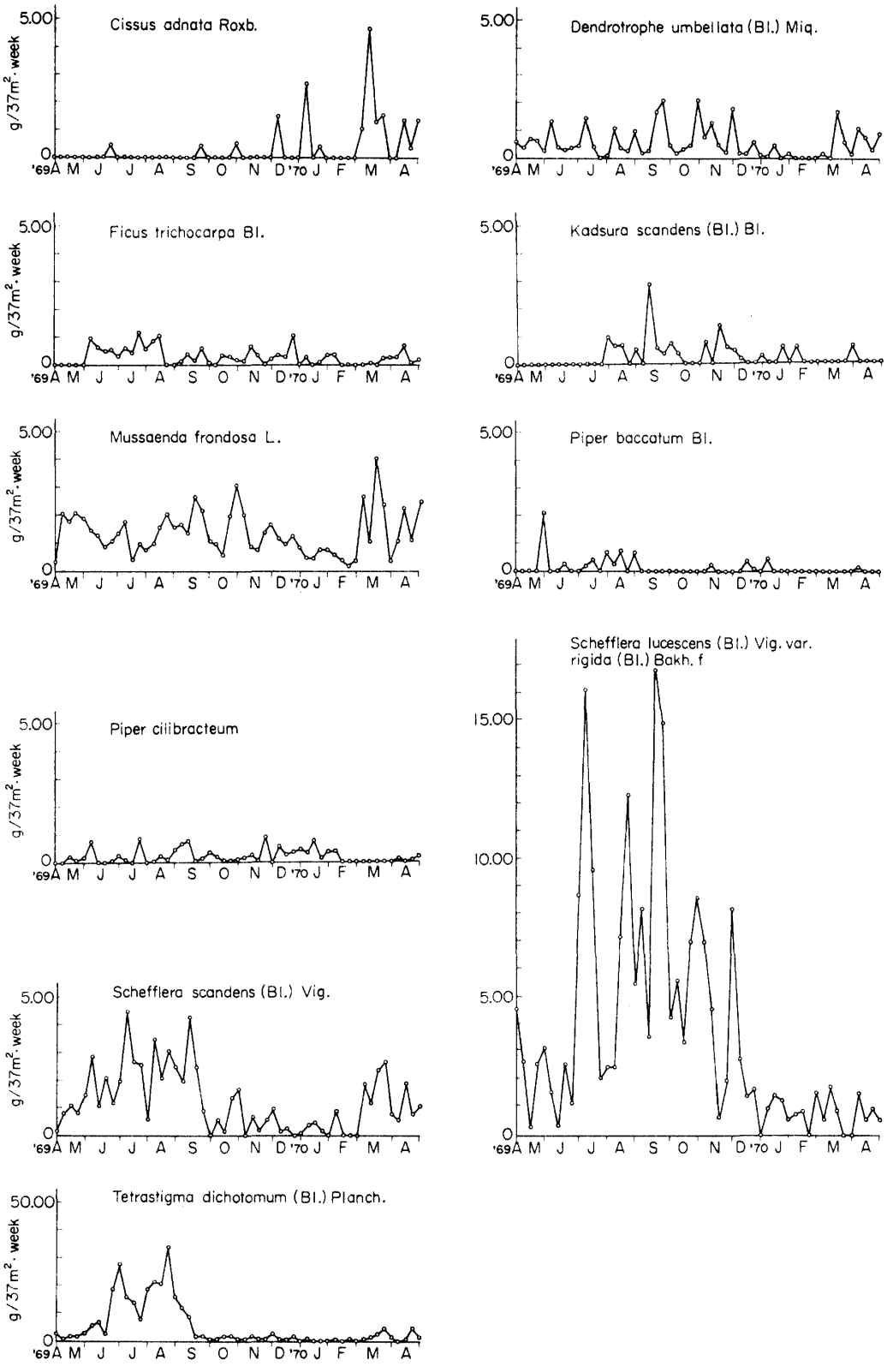
Appendix (1)"


Saurauia blumiana Benn.
Saurauia pendula Bl.
Saurauia reinwardtiana Bl.
Schima wallichii (DC.) Korth ssp. noronhae (Reinw. ex Bl.) Bloembergen
Strobilanthes cernua Bl.
Symplocos fasciculata Zoll.
Turpinia sphaerocarpa Hassk.
Vernonia arborea Buch.-Ham.
Villebrunea rubescens (Bl.) Bl.
g/37m²·week
'69A M J J A S O N D '70 J F M A

Appendix (1)‴


Agalmyla parasitica (Lamk.) O.K.
Diplycosia heterophylla Bl.
Ficus deltoidea Jack
Ilex spicata Bl.
Loranthaceae
Medinilla laurifolia (Bl.) Bl.
Medinilla speciosa (Reinw. ex Bl.) Bl.
Rhododendron javanicum (Bl.) Benn.
Vaccinium laurifolium (Bl.) Miq. var. ellipticum (Bl.) Sleum.
43.14
24.08
Vaccinium laurifolium (Bl.) Miq. var. laurifolium
Vaccinium lucidum (Bl.) Miq.
g/37m². week
'69A M J J A S O N D '70 J F M A

Appendix (2)


Cissus adnata Roxb.
Dendrotrophe umbellata (Bl.) Miq.
Ficus trichocarpa Bl.
Kadsura scandens (Bl.) Bl.
Mussaenda frondosa L.
Piper baccatum Bl.
Piper cilibracteum
Schefflera lucescens (Bl.) Vig. var. rigida (Bl.) Bakh. f
Schefflera scandens (Bl.) Vig.
Tetrastigma dichotomum (Bl.) Planch.
g/37m²·week
'69A M J J A S O N D '70 J F M A

Appendix (3)